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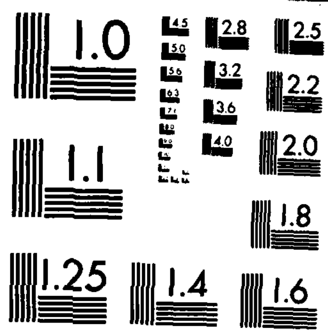

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A FORTRAN PROGRAM
FOR
DEEP SPACE SENSOR ANALYSIS

THESIS

AFIT/GSO/OS/84D-5

GLENN KINGI HASEGAWA
CAPTAIN USAF

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AFIT/GSO/OS/84D-5

A FORTRAN PROGRAM FOR DEEP SPACE SENSOR ANALYSIS

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

by

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Graduate Space Operations

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Glenn Kingi Hasegawa

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Abstract

The deep space satellite tracking network presently in operation is not capable of providing enough observations to monitor all deep space satellites at optimum levels currency. The major reason for this deficiency is the reliance upon the five GEODSS sensors for the bulk of the observations. All though only three of the five sites are presently in operation, the three in operation are only capable of providing 40% of their maximum tracking capacities. Because the GEODSS sensors are optical, they are limited to operation only during darkness and clear skies. If we assume that this 40% of maximum is to continue, the addition of the last two GEODSS sensors will only maintain the present capabilities since the Baker-Nunn cameras are scheduled to be shut down when the last two GEODSS sites are operational.

As a tool used for the above analysis, a computer program was developed using Fortran 77 language. The program uses as inputs; the distribution of synchronous satellites, total deep space satellite size, sensor locations and sensor visibility limits. The program determines the number of satellites visible to each individual sensor, the number of tracks required for each sensor, identifies areas of overlapping coverage between adjacent sensors, and the number of satellites within the areas of overlapping coverage.

TO

SANDY

JEREMY AND CHRISTOPHER

CHAPTER 1

INTRODUCTION

Background

As the former Chief of the Deep Space Operations shop in the Cheyenne Mountain Complex in Colorado Springs, I became aware of many weaknesses in the mission of deep space satellite tracking. I would like to focus my attention in this thesis on the capabilities of the United States to track deep space satellites. Where are our weaknesses in performing this mission? What have we done to alleviate the problem? What more do we have to do? What will be the impact of acquiring new sensor systems? I will restrict myself to the discussion of tracking deep space satellites since this is the area I perceived as most vulnerable as far as the ability of the United States to detect and track satellites representing a threat to U.S. satellite assets.

Deep space satellites present a more difficult problem in terms of catalog maintainence because many of the satellite orbits are out of range or at the very limits of our present tracking capabilities. Because of their slow angular motion relative to near earth satellites, deep space satellites are observed by fewer sensors which means that their orbits must be calculated with less data.

The geosynchronous satellite is unique because of its apparent stationary position over a predetermined point over the equator. This position enables constant coverage over approximately one third of the earths surface. Conversely, the satellite can be seen only by those sensors in the same

third of the earth's surface. Our ability to maintain accurate positional data on a synchronous satellite is therefore, a function of the longitudinal subpoint of the satellite and the sensors in that third of the world.

The need to maintain accurate orbital data is generated by many requirements. The most critical requirement is the prevention of loss of use of satellites which support military functions. The most general requirement is generated by the Space Command's mission to track and maintain orbital data on all man-made satellites. With the increased use of the synchronous orbit this task has become increasingly difficult. Since the Soviets also use synchronous satellites, our ability to adequately track these satellites has become more urgent. The increased use of the synchronous orbit has generated a potential of satellite to satellite interference or physical collision between two satellites. Studies by Dr Chobotov and Hechler have shown that probabilities of this occurance are on the order of 10^{-6} to 10^{-7} per year (1,38; 3,361). Our ability to predict potential collision situations is limited to regions of adequate sensor coverage. Even in regions where sensor coverage is adequate, uncertainty remains due to inacurracies of the sensors themselves.

The problem is complicated by the rapid growth of the deep space population. Sensors are becoming overwhelmed with routine tracking responsiblities which reduces the tracking time per satellite. The result is reduced overall quality of

deep space satellite catalog maintenance. Present deep space satellite tracking is handled by a system of three GEODSS sensors, three deep space radars, three Baker-Nunn cameras and some near earth radars.

A number of options are available to enhance the deep space sensor network in preparation for the continued satellite population growth. They include;

1) Addition of GEODSS 4 AND 5
2) Spaced-Based Surveillance System (SBSS)
3) Two new Haystack radars
4) C-Band Radar upgrades

This research effort will consider only ground based sensors. Specifications on the different sensors will be furnished by Space Command.

Current Deep Space Sensors

Observations on the deep space satellites are provided by four sources - optical sensors, electro-optical sensors, radar sensors, and contributing outsides agencies.

The optical sensors are the Baker-Nunn cameras, which are the oldest cameras presently in service to track deep space satellites. The first production model was deployed on 3 October, 1957, the day before Sputnik I was launched. They are essentially cameras attached to powerful telescopes which can photograph a satellite reflecting sunlight against a star background. The location of the satellite can be determined by measuring the satellites positions relative to

345 degrees east longitude to 45 degrees east longitude. Using the above procedure, the border satellites are determined to be 251 and 25. Next, the problem is segmented into determining the number of satellites between 345 degrees east longitude and 0 degrees longitude, and 0 degrees longitude to 45 degrees longitude. In the first segment the maximum number of synchronous satellites is known (variable maxsat) so the number of visible satellites is maxsat minus 251 plus 1 or 264 - 251 + 1 = 14. In the second segment, the number of visible satellites is the value of the upper border limit satellite or in this case 25. The total number of satellites visible to this arbitrary sensor is then 14 + 25 = 39. The above procedures are repeated for each sensor and the number of visible synchronous satellites are stored in the array "vissat".

Subroutine SYNCTR

This subroutine will calculate the number of tracks required for the synchronous satellites visible to each sensor. The deep space satellites are divided into two categories. Category I contains those satellites which are of high interest and therefore require at a minimum two tracks per pass or shooting period. Category II contains those routine satellites which require only one track per pass or shooting period. The term shooting period is defined as the amount of time of sensor operation per 24 hour period.

For this program, a satellite sequence number scheme will be used to determine the number of synchronous satellites within the sensor visibility limits. Each satellite subpoint was given a sequential number starting at 1 for the first satellite east of zero degrees longitude and ending at 264 for the last satellite east of zero degrees longitude. The calculation of the number of visible synchronous satellites becomes a simple subtraction of the lower limit border satellite number (subpoint position which is farthest west) from the upper limit border satellite number (subpoint position which is farthest east).

For example, consider an arbitrary sensor which has visibility limits of 10 degrees east to 80 degrees east. Refering to the satellite distribution file (Appendix C), the satellite sequential number corresponding to 10 degrees is 5 and the satellite sequential number coresponding to 80 degrees is 65. The number 5 was determined as follows. The program looks at the longitude values within the satellite file and picks the smallest satellite number whose corresponding longitude is greater than or equal to 10 degrees east longitude. Similiarly, in determining the value of 65 the program picks the largest satellite number whose longitude is less than or equal to 80 degrees east longitude.To calculate the number of visible satellites we merely subtract 5 from 65 and add 1 to get 61.

The process is a little more complicated for a sensor whose visibility limits straddle zero degrees. Take for example another arbitrary sensor whose visibility limits are

Subroutine SYNVIS

Subroutine Synvis will determine the number of synchronous satellites visible to each of the deep space sensors. The first step is to assign to variable "lwlim" the value of the lower synchronous longitudinal visibility limit contained in the sensor file. This value represents the longitudinal subpoint of the most western synchronous satellite visible to this sensor. Next, variable "uplim" is assigned the value of the upper synchronous longitudinal visibility limit contained in the sensor file. This value represents the subpoint of the most eastern synchronous satellite visible to this sensor.

The next task is to determine the sychronous satellites which are closest to the longitudinal visibility limits without going beyond the limits. Once the border satellites have been determined, the subroutine will then calculate the number of synchronous satellites which lie between the two border satellites. The result will be the number of synchronous satellites which are visible to that particular sensor. Because the distribution of synchronous satellites is not uniform, the number of visible satellites will vary depending on the location of the sensor as well as the size of the synchronous visibility limits. The actual logic used to determine the number of visible satellites is rather simple. The synchronous satellite file contains the longitudinal subpoint of the actual satellite distribution as of 30 July 1984 (Appendix C-1).

results of the preceding subroutines to calculate the total number of tracks required for all of the deep space satellites. Since the individual workloads of the sensors will vary depending on geographic locations, subroutine "wordis" determines what the workload is for each individual deep space sensor. In order to be able to shift workloads from overloaded sensors to sensors with less loading it is necessary to determine how many satellites are within coverage of more than one sensor. Subroutine "ovrlap" does this task. Finally, subroutine "print" will consolidate the results of the entire program and print them.

Main Module

The program begins by first reading in the data file. As a check of the reading process the program can, at users option, print the data it has read. After completion of the reading process, the program will call the following subroutines;

1. synvis
2. synctr
3. nsynvi
4. nsyntr
5. todstr
6. wordis
7. ovrlap
8. print

In the following sections the functions of each of the subroutines will be described.

contains the following information.

1. The number of deep space sensors
2. The maximum number of deep space satellites
3. Total number of non-synchronous satellites
4. A list of all synchronous satellites and their respective longitudinal position. This list is ordered by longitude starting at 0 and going east to 360 degrees longitude.
5. A table of all the deep space sensors along with the following information;
    A. sensor number
    B. sensor location
    C. synchronous longitudinal visibility
    D. maximum tracking capacity

Program Structure

The program consists of a main module and 8 subroutines. The main module serves the purpose of reading in the data files and calling the subsequent subroutines. Subroutine "synvis" determines the number of synchronous satellites visible to each of the deep space sensors. Base on the results of "synvis", subroutine "synctr" will calculate the number of tracks required for each sensor on synchronous satellites. Subroutine "nsnvi" determines the number of non-synchronous satellites visible to each of the deep space sensors. Subroutine "nsyntr" follows and calculates the number of tracks required for each sensor on the non-synchronous satellites. Subroutine "todstr" combines the

METHODOLOLGY

This simulation model will be developed using Fortran 77. The model will incorporate the geographical location of present sensors and future sensors. Workload capabilities will be calculated as is done with NORAD's deep space tasking program. For example, each sensor is tasked a maximum of 10 tracks per hour of operation. Tracking requirements will be determined by placing satellites in one of two categories. Category 1 will consist of those high interest satellites which require quality orbit predictions and therefore more observations per satellite. Category 2 will consist of the rest of the satellites whose orbits are fairly stable and require minimal tracking. The summation of these two requirements for the two satellite categories will generate the total track requirement for the entire deep space network. The remaining task will be to distribute the total track requirement realistically to the various geographic locations of the present sensors and proposed sensors. It is assumed that all sensors have equal visibility of the non-synchronous satellites. This assumption was made because the precession of these satellites will eventually place them in view of all of the sensors at some time.

PROGRAM DEVELOPMENT

The operation of this program will be explained by simulating an actual run of the program through one cycle. To begin with a data file must be created. The data file

CHAPTER 2

METHODOLOGY/PROGRAM DEVELOPMENT

INTRODUCTION

The general approach to this thesis effort was to generate a Fortran program which would use the following information as inputs:

1) Sensor locations and limits (synchronous visibility limits)

2) Sensor maximum tracking capacities (tracks per day)

3) The distribution of the geosynchronous satellite population (longitudinal subpoints)

4) The percentage of geosynchronous satellites which fall into the catagory of high interest or high priority satellites

5) The number of deep space satellites which are not geosynchronous

6) The percentage of *non-geosynchronous* satellites which fall into the category of high interest or high priority satellites

Given the above inputs the program output should show how the deep space tracking workload is distributed among the input sensors. It will also indicate if the workload is within the tracking capacity of each individual sensor.

The program will allow as variables, the number of sensors, the location of the sensors, the tracking capacity of the sensors, and visibility limits of the sensors. In addition the population of satellites may be varied as well as the distribution of the synchronous satellites.

vulnerable to a collision with an unknown or unobserved satellite. To date, there is no indication that any work has been done to develop a model of the deep space tracking network in order to anticipate the demands and requirements of the future and thereby have a quantitative analysis of performance of proposed improvements.

4) Evaluate some improvements to the deep space network.

SCOPE

This research will be based mainly on information derived from the current deep space population. Estimates will be made on future requirements in terms of accuracy requirements and deep space satellite population growth. As mentioned earlier, only ground based sensors will be considered in this model.

For this thesis, the range for the number of sensors will be limited to 12 or two more sensors than what is presently in operation. The actual type of sensor or type of observation an individual sensor will generate will not affect the results of this program since these are not inputs to the program.

Literature Review

To date my literature search has shown that there is concern about the increasing satellite population and our ability to monitor all objects in orbit about the earth (1,38; 3,361; 4,707; 7,249; 8,410). Probabilities of collisions have been calculated. To decrease the probability of collision, satellites are being designed to be removed from conjested areas when their mission has been completed. Satellites are also being designed to consolidate a number of missions into one satellite. Inadequate tracking increases the potential of losing satellites resulting in a situation where a satellite may be

will the addition of new sensors improve the capability to track all required satellites? How will the location of the new sensors impact the tracking capability? The last two GEODSS sensors are to be located at Diego Garcia and at a location in Portugal. Will these sensors alone resolve the problem of tracking deep space satellites? If so can an estimate be made as to how the deep space tracking network will fair in the next century? Can we predict our tracking requirements based on projected deep space satellite population growth? The GEODSS sensors are suppose to replace the aging Baker-Nunn sensors. However, should the Baker-Nunns be shutdown or should they be used to help maintain currency to the deep space satellite catelog?

Research Question

Can a Fortran program be designed to evaluate the effectiveness of proposed sensor additions and improvements?

Objectives

The overall objective of this research is to develop a Fortran model which can be used to provide a quantitative analysis of proposed deep space satellite tracking networks. Specific subobjectives are:

1) To find a method for estimating the required number of tracks or observations necessary for total population monitoring.
2) To find a method for estimating the required number of tracks or observations necessary for high quality data generation.
3) To find a method for determining geographic locations which would best accomplish subobjectives 1 and 2.

shown to be able to fulfill this need, Pirincilik, however, has yet to demonstrate its ability to meet this requirement.

The final category of sensors are actually near-earth sensors which are able to track those deep space satellites which pass within the range of the near earth sensors. The satellites are generally those in highly eccentric orbits whose perigee heights are below 1000 km. The quantity of data available from these sensors is minimal but because of the radar type observations, they are very valuable. Some of the near earth sensors which provide this type of support are Eglin, NAVSPASUR, and the PAVE PAWS sites at Otis and Beale.

Problem Statement

The growing deep space satellite population has generated concern on the ability of the United States to monitor all of the satellites and to provide quality elsets on a select few .

The question which drives this research effort is how sensor additions or improvements will affect the mission of tracking deep space satellites. Presently, a tasking program in Cheyenne Mountain (DSTASK) generates the requirements for data collection for each individual satellite and then assigns the satellite to sensors for tracking. Because of limited tracking time many sensors are unable to track all satellites that are assigned to them. Hence the lower priority satellites are not tracked. How

Besides the GEODSS sensors, there are two other electro-optical sensors which provide tracking support for NORAD. The Air Force Eastern Test Range (AFETR) Range Measurements Laboratory (RML) is located in Malibar, Florida. Like GEODSS, Malibar uses a 48 inch telescope with a television camera to detect and track satellites. The Malabar sensor is not funded for NORAD support since its research and development nature is not optimally suited to the spacetrack mission. However, Malabar has demonstrated the capability to suppport NORAD with satellite observations on selected deep space events.

AMOS Maui is another electro-optical sensor with unique capabilities. Located on Maui in the Hawaiian Islands, it is designed to be a multi-purpose sensor with several missions. Besides gathering deep space metric data, its measurements systems will include multicolor infrared radiometry, laser illumination and ranging, direct film and TV imaging, and interferometry.

The third group of deep space sensors are catagorized as deep space radars. They are located at Millstone Hill, Mass.; Altair; and Pirincilik, Turkey. Radar operations have the distinct advantage of not being affected by weather, darkness, or moon conditions. However, because of their narrow beams they have limited search capabilities. Radars can also provide range information which optical sensors are unable to provide. The intent of the three radars was to fill the requirement for 24 hour coverage of deep space satellites. Millstone and Altair have already

way to the moon, a distance of 180,000 km.

The successor to the Baker-Nunn cameras is the family of electro-optical sensors. All but two belong to the Ground Based Electro-Optical Deep Space Sensor System (GEODSS).

The GEODSS telescope is steered by a computer. During satellite acquisition, the satellite along with the star background appears before an operator on a TV monitor. Observations may then be initiated by the operator in the manual mode. In the automatic mode, observations will be taken automatically. If a satellite is not immediately found, a search mode can be initiated about the expected position. The search may utilize all three telescopes and utilize acquisition aids such as different telescope field of view, a Moving Target Indicator(MTI), or a target signal integrator. Under normal conditions the three telescopes operate independent of each other thereby giving the GEODSS site the potential of gathering 3 times the data of a Baker-Nunn sensor. Automation of data collection has enabled real time satellite observation collection as well as real time transmission of data to NORAD.

There are presently three operational GEODSS sites. They are located at Soccoro, New Mexico; Maui, Hawaii; and Tagu, Korea. Two additional GEODSS sensors are planned for Diego Garcia in the Indian Ocean and southern Portugal. The last two sites are expected to be operational by 1988.

the known position of the stars.

The advantages of the Baker-Nunn cameras are as follows:

1. Observations can be made on objects which are out of range of radars as long as the objects are illuminated.

2. The Baker-Nunn site is much less expensive to operate than a radar site or electro-optical site.

3. Baker-Nunn cameras have excellant search capabilities because of their large field of view which spans 5 degrees in width and 30 degrees in length.

4. The camera can provide accurate satellite positional data, within 25-90 seconds of arc with field reduction, and 2-6 seconds of arc with precision reduction.

The two main disadvantages are limited operations and non-real time data transmission. The limited operations are due to the fact that optical sites require darkness, satellite illumination, and clear skies. The non-real time is due to the need to process photographic film and manually reduce the film to produce satellite observations.

In spite of their limitations, the Baker-Nunn cameras have demonstrated some amazing capabilities. They routinely make satellite observations of satellites such as the Soviet Molniya satellite at its farthest point from earth, approximately 40,000 km. A Baker-Nunn was also able to track Vanguard I, a 6-inch spherical satellite at a height of 2400 miles. This is equivalent to photographing a shiny 30 caliber bullet in flight at a distance of 200 miles. The Baker-Nunns were also able to track an Apollo mission half-

Since this program does not look at individual satellites this division is simplified by taking a percentage of the total visible satellites as high interest and the rest as Category II. The percentage used in this program was determined by examination of the actual tasking program used by NORAD and evaluating the sensor workload division of high interest and routine satellites. Tracking requirements for synchronous satellites per sensor is determined by multiplying the number of visible satellites by the percentage of high interest satellites. The high interest satellites are then multiplied by two since these require two tracks per pass at a minimum. The remainder of the satellites require only one track per pass. The two tracking determinations are added together for the combined track requirement for synchronous satellites per sensor. This procedure is repeated for each sensor and the respective track requirement is stored in the array "totstr".

The last step for this subroutine is to calculate the total track requirement for the total population of synchronous satellites. This is calculated by summing the values of each individual sensor track requirement for synchronous satellites. The sum is then stored in the variable "wortr". Note that this sum for the number of tracks required on all synchronous satellites does not take into account that some of the satellites are visible to more than one sensor. Therefore, many satellites may receive more than the minimum amount of tracks. To determine the

absolute minimum number of tracks required for all of the synchronous satellites, a strictly percentage calculation was done on the total synchronous satellite population. Since it was determined that the 20% of the synchronous satellites fell into the high interest category, the calculated number of high interest synchronous satellites was multiplied by two and added to the number of routine sychronous satellites to yield the estimated minimum amount of tracks necessary for all of the synchronous satellites. This value was then stored in the variable "syntot".

Subroutine NSYVIS

This subroutine calculates the number of non-synchronous satellites visible to each sensor. As discussed earlier, it is assumed that the total population of non-synchronous satellites are uniformly distributed about the earth, hence all sensors see an equal amount of non-synchronous satellites and the tracking workload can be distributed evenly among the sensors. With this assumption, the determination of the number of visible non-synchronous satellites is a simple matter of dividing the number of non-synchronous satellites by the number of sensors. This number is then store in the variable "nsyvis".

Subroutine NSYNTR

This subroutine calculates the number of tracks required for the non-synchronous satellites visible to each sensor. Since each sensor has the same number of non-synchronous satellites visible to it this calculation is the same for all sensors. The same procedure that was used in subroutine "synctr" to determine the tracking requirement for the synchronous satellites is also used here. The same percentage of high interest satellites is used as well as the same percentage of routine satellites. Two tracks are required for the high interest satellites and only one track is required for the routine satellites per pass. The non-synchronous track requirement per sensor is then stored in the variable "nstrsn". An additional calculation is then made to determine the combined non-synchronous track requirement for all sensors. This value is stored in the variable "tonstr".

Subroutine TODSTR

This subroutine calculates the minimum total deep space tracking requirement "todtr" and the redundant deep space tracking requirement "redtr". The value of "todtr" is calculated by summing the value of the total non-synchronous tracking requirement "tonstr" and the total synchronous track requirement "syntot". The value of "redtr" is determined by summing "tonstr" and the world wide synchronous tracking requirement "wortr". Note that the value of "wortr" does not subract tracks due to overlapping

coverage of adjacent sensors. Hence, the value of "redtr" is significantly larger than "todtr" which is calculated without using sensor visibility information. In reality, if a synchronous satellite is visible to more than one sensor it is tasked to at least two of the sensors. This ensures the generation of element sets with data from more than one sensor. In addition, this supplies a backup for incidences of sensor down times due to uncontrollable circumstances such as bad weather conditions.

Next to determine the deep space sensor tracking capacity, the individual tracking capacities are summed. This sum is stored in the variable "dsscap". The difference between the variables "dsscap" and "redtr" represents a deficiency or surplus in the total deep space sensor tracking capability when the total deep space satellite population distribution is assumed to be a uniform distribution. This difference is sometimes mistakenly taken as an indicator of the capabilities of the sensor network. However, this is not the case since we are not using a uniform distribution of synchronous satellites, so it becomes necessary to evaluate further with subroutine WORDIS.

Subroutine WORDIS

This subroutine determines the workload distribution of sensors and calculates the difference between individual sensor tracking requirements and tracking capacities. Individual sensor tracking requirements are calculated by

adding the values of the synchronous track requirement stored in the array "totstr" and the non-synchronous track requirement per sensor stored in the variable "nstrsn". This result is then stored in the three dimensional array "wkld". Note that the individual sensor tracking requirements are calculated using the values in the array "totstr", hence, the tracking requirements include dual tracking of adjacent sensors with overlapping coverage. By subtracting the sensor workload "wkld" from the sensor tracking capacity, an evaluation can be made regarding individual sensor workload. The difference is then stored in the array "wkld" . The array "wkld" stores the sensor number, the sensor workload, and the difference between the sensor workload and the sensor work capacity.

Subroutine OVRLAP

The purpose of this subroutine is to determine the number of satellites which are visible to more than one sensor due to overlapping coverage of adjacent sensors. This information will be used to shift workloads from an overloaded sensor to one which has a smaller workload of satellites to track.

The algorithm used here is similiar to the one used in the first subroutine "synvis". The method differs in that the values used for the variables "lwlim" and "uplim" must be obtained from two different sensors. Once these variables have been determined the subroutine merely uses

the steps used in subroutine "synvis" to calculate the number of satellites which are visable to both sensors in question.

For example, sensor number 1 has visibility limits of the synchronous belt of 241 degrees east longitude to 350 degrees east longitude.(table 16 in chapter 3) The subroutine starts with sensor number 2 and examines whether or not either of sensor number 2 visibility limits fall between the visibility limits of sensor number 1. The visibility limits for sensor number 2 are 321 degrees east to 75 degrees east. The eastern limit of sensor 2 overlaps with the western limit of sensor 1. Satellites within 321 degrees east to 350 degrees east are visible to both sensors. Using the method outlined in the subroutine "synvis", the number of satellites visible to both sensors is 30. This result is then stored in the array "ovlp" which contains the number of satellites visible to each pair of sensors with overlapping coverage.

Subroutine PRINT

The purpose of the final subroutine is to consolidate and print the calculations of the entire program. It begins with an index of sensor numbers and their respective names. Next follows a table containing the number of synchronous satellites visible to each sensor. The next entries represent the combined deep space tracking capacity, the total deep space tracking requirement, and the total redundant deep space tracking requirement respectively. In

the next table, individual sensor redundant tracking requirements, tracking capacities and the difference between the capacity and requirement are printed. The last item is and array containing the number of satellites visible to sensors with overlapping coverage.

Verification and Validation

Verification of this program was achieved by a manual check of several samples of sensors for comparison of expected tracking requirements, number of visible satellites, and calculation of satellites in dual visibility of sensors with overlapping coverage. The expected results were obtained in all cases.

Specifically procedures for verification started with the verification of subroutine "synvis". The visibility limits from the sensor file were used to determine the low and high border satellites. Next, using the input satellite file, the number of satellites between these satellites were manually counted. This number was compared to the number calculated by the subroutine and found to be identical. This procedure was done for all twelve sensors used in this study. Next, the number of required tracks on all deep space satellites visible to an individual sensor was manually calculated for 5 randomly selected sensors and compared to the results calculated by the subroutine "wordis". The comparison between the manually determined results and the computer determined results showed no difference.

The verification of the subroutine "ovrlap" was done by a manual determination of the overlapping coverage of all possible pairs of sensors. The boundaries of these overlapping coverage areas were compared with those calculated by the subroutine "ovrlap" and found to be identical. The second part of this subroutine uses the procedures of the subroutine "synvis" to determine the number of satellites within the overlapping coverage, so it was not necessary to verify this portion again.

The purpose of this program was to represent the workload distribution of the deep space tracking network. Since the best indicator of sensor workload is satellite tasking, several ideas from the NORAD tasking program were utilized to help in the program design. The intent was not to duplicate the NORAD tasking program. Therefore even though the product of this program is compared to the NORAD tasking program, an exact correspondence is not expected nor required. The main concern is that this program generate the same relative workload between sensors as is seen in the real world sensor tasking. Differences between this program and the real world can be accounted for by the assumptions made in program design.

The first assumption states that the distribution of synchronous satellites population is the major factor in the determination of sensor loading. The non-synchronous satellites are assumed to have a uniform distribution and thereby placing an equal workload on all sensors.

The next assumption is made in the determination of track requirements. In the real world, tracking requirements are determined by tasking categories and tasking suffixes. Five tasking categories are used and each category has five tasking suffixes. The categories are used to assign priorities and the suffixes are used for setting the number of required tracks. In this Fortran program all satellites are placed in one of only two categories with no suffixes.

Category 1 is for the high priority or high interest satellites. These satellites require a minimum of two tracks per pass or shooting period. The remainder of the satellites are category 2 or the routine satellites which require only one track per pass or shooting period. It is obvious that this Fortran program will not duplicate the results of the NORAD tasking program, however, the relative workload between sensors is comparable. The current real world configuration data was compared with this Fortran model. Data provided by the Deep Space office at NORAD indicates that the real world has an average number of tracks tasked per satellite of 2.05 per day. The Fortran model calculates 2.35 (based on value of "redtr" divided by the total number of deep space satellites) tracks tasked per satellite per day. Both of these numbers reflect satellites tasked to more than one sensor, hence some satellites may be tracked by as many as 4 or 5 sensors in one day. In reality, only about 50% of the tasked tracks are obtained.

Hence,in the real world the actual number of tracks per satellite per day is 1.03. This corresponds to the minimum number of tracks per day, 1.20 (base on value of "todtr" divided by the total number of deep space satellites), that is calculated by the Fortran program.

CHAPTER 3

EXPERIMENTAL RESULTS

Experimental Design

For this thesis effort, fifteen runs were made. Each run represents a different mode of operation for the sensors selected. The following variables were considered in this evaluation:

1. The number of sensors
2. The maximum tracking capacity of each sensor
3. The location of the sensors

Mode 1

I chose as the starting point, the current configuration of deep space sensors. This consisted of 3 GEODSS sites (sites I,II,and III), Motif Maui optical site, 3 Baker-Nunn sites, and the three deep space radars.

Mode 2

Since the radar site in Pirincilik, Turkey has not yet proven to be able to generate useful date on deep space satellites, this mode is identical to mode 1 with the exception of the Pirincilik radar being left out.

Mode 3

The completion of the GEODSS network is expected to add sites in Diego Garcia and Portugal. Hence, this mode will evaluate the sensors of mode 1 with the addition of two more GEODSS sites.

Mode 4

With the completion of the GEODSS sensors, the Baker-Nunn sites are expected to be phased out. This mode will evaluate the effect of the loss of the 3 Baker-Nunn sites to mode 3

Mode 5 through Mode 8

Modes 5 through 8 are identical to modes 1 through 4 with the exception that the maximum tracking capacity for each sensor has been decreased by 50% for the Baker-Nunn cameras, 60% for the GEODSS and MOTIF sensors, and 25% for the deep space radars. These decreases represent the average response of the sensors to NORAD's tasking at this writing. The decreases are due to the limitations due to weather, daylight, and sensor down times.

Mode 9

Mode 9 consist of only the three deep space radars. The purpose of this is to represent the deep space sensor response to a real time crisis need of observation on objects of high interest. An area of interest here is sensor overlap between the three radars. Of course the radars will only be required to track satellites of high interest.

Mode 10

This mode is similiar to Mode 9 with the exception that here the maximum tracking capacity for each sensor has been decreased by 25%. The purpose again is to evaluate the real time tracking capability in a 24 hour environment.

Mode 11 through 15

Modes 11 through 15 provide information for sensitivity analysis for the configuration represented by mode 4. The purpose is to determine at what level of tracking capacity reduction is this configuration still capable of providing the required number of tracks necessary for optimum maintenence of the current deep space satellite population. For all runs of this test the reduction of the deep space radars will be maintained at 15%. Since the MOTIF sensor is only a contributing sensor it will not be used in these runs. Modes 11 through 15 will represent a reduction in the GEODSS sensors by 10%, 20%, 30%, 40%, and 50% respectively.

Results

Tables 1 through 15 represent the results of the computer runs on the 15 modes. Table 16 contains the sensor information used by the program for satellite visibility calculations. Table 16 is arranged as follows: The sensors are represented by the rows. The columns contain information specific to each sensor. Specifically from left to right the columns contain the sensor number, sensor latitude, sensor longitude, eastern visibility limit,

western visibility limit, and maximum tracking capacity. Appendix C contains the synchronous satellite longitudinal subpoints used to determine sensor visibility of synchronous satellites.

Appendix B contains a printout with all print statements within the program activated for mode 1. In Tables 1 through 15 the print statements in the print subroutine only were activated. All other print commands within the program were suppressed. This option included within this program was used as a trouble shooting tool.

The table of results will be presented in the following format:

1. The first item is the number of sensors used for the particular run. This is represented by a value assigned to the variable "num".

2. The next entry is the number of synchronous satellites contained in this data file. The variable "maxsat" contains this value.

3. The third item is the total number of non-synchronous satellites the run is based on.

4. Next comes the number of synchronous satellites visible to each sensor.

5. The combined deep space tracking capacity is next. This value is simply the summation of the last column of deep space sensor (which contains the individual sensor tracking capacity) file found in table 16.

6. The total deep space tracking requirement follows item 5. Note here that this number represents the

```
num =  9
maxsat = 264
nonsyn = 4ØØ
Number of synchronous satellites visible to each sensor
Sensor number        Number of satellites

      1                          91

      2                          93

      3                          83

      4                          88

      5                          8Ø

      6                          77

      7                          77

      8                          88

      9                         125
Combined Deep Space Track Capacity =  772
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1436

Workload Distribution
Sensor number          No. of Required Tracks    Difference
      1                         16Ø                 -1ØØ
Sensor number          No. of Required Tracks    Difference
      2                         163                 -1Ø3
Sensor number          No. of Required Tracks    Difference
      3                         151                  -91
Sensor number          No. of Required Tracks    Difference
      4                         157                  -13
Sensor number          No. of Required Tracks    Difference
      5                         148                   -4
Sensor number          No. of Required Tracks    Difference
      6                         143                    1
Sensor number          No. of Required Tracks    Difference
      7                         143                 -1Ø3
Sensor number          No. of Required Tracks    Difference
      8                         157                  -97
Sensor number          No. of Required Tracks    Difference
      9                         2Ø2                 -142

overlap visibility array
    Ø   3Ø   51   58    Ø   25   25    2   91
   3Ø    Ø    Ø    Ø    3    Ø    Ø    Ø   39
   51    Ø    Ø   81    Ø   57   57   34   76
   58    Ø   81    Ø    Ø   55   55   32   83
    Ø    3    Ø    Ø    Ø   19   19   53    Ø
   25    Ø   57   55   19    Ø   77   54   5Ø
   25    Ø   57   55   19   77    Ø   54   5Ø
    2    Ø   34   32   53   54   54    Ø   27
   91   39   76   83    Ø   5Ø   5Ø   27    Ø
```

TABLE 6

MODE 6

Sensor Number 1 =	Baker-Nunn,	St Margarets,	# 27
Sensor Number 2 =	Baker-Nunn,	San Vito,	# 25
Sensor Number 3 =	Baker-Nunn,	Edwards,	# 30
Sensor Number 4 =	GEODSS,	Soccoro,	#210
Sensor Number 5 =	GEODSS,	Korea,	#220
Sensor Number 6 =	GEODSS,	Maui,	#230
Sensor Number 7 =	MOTIF,	Maui,	#951
Sensor Number 8 =	Radar,	Altair,	#334
Sensor Number 9 =	Radar,	Millstone,	#369

Maximum Tracking Capacity --Reduction/New value

Baker-Nunn --- 50% /60 Tracks per day

GEODSS and MOTIF -- 60%/144 Tracks per day

Radars ---25%/60 Tracks per day

```
num =  10
maxsat = 264
nonsyn = 400
Number of synchronous satellites visible to each sensor
Sensor number      Number of satellites

     1                           91

     2                           93

     3                           83

     4                           88

     5                           80

     6                           77

     7                           77

     8                           88

     9                          125

    10                          126
Combined Deep Space Track Capacity =  832
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1586

Workload Distribution
Sensor number          No. of Required Tracks    Difference
     1                        156                    -96
Sensor number          No. of Required Tracks    Difference
     2                        159                    -99
Sensor number          No. of Required Tracks    Difference
     3                        147                    -87
Sensor number          No. of Required Tracks    Difference
     4                        153                     -9
Sensor number          No. of Required Tracks    Difference
     5                        144                      0
Sensor number          No. of Required Tracks    Difference
     6                        139                      5
Sensor number          No. of Required Tracks    Difference
     7                        139                    -99
Sensor number          No. of Required Tracks    Difference
     8                        153                    -93
Sensor number          No. of Required Tracks    Difference
     9                        198                   -138
Sensor number          No. of Required Tracks    Difference
    10                        198                   -138

overlap visibility array
     0    30    51    58     0    25    25     2    91    26
    30     0     0     0     3     0     0     0    39    89
    51     0     0    81     0    57    57    34    76     0
    58     0    81     0     0    55    55    32    83     0
     0     3     0     0     0    19    19    53     0    40
    25     0    57    55    19     0    77    54    50     0
    25     0    57    55    19    77     0    54    50     0
     2     0    34    32    53    54    54     0    27    13
    91    39    76    83     0    50    50    27     0    35
    26    89     0     0    40     0     0    13    35     0
```

TABLE 5

MODE 5

Sensor Number 1 =	Baker-Nunn,	St Margarets,	# 27
Sensor Number 2 =	Baker-Nunn,	San Vito,	# 25
Sensor Number 3 =	Baker-Nunn,	Edwards,	# 30
Sensor Number 4 =	GEODSS,	Soccoro,	#210
Sensor Number 5 =	GEODSS,	Korea,	#220
Sensor Number 6 =	GEODSS,	Maui,	#230
Sensor Number 7 =	MOTIF,	Maui,	#951
Sensor Number 8 =	Radar,	Altair,	#334
Sensor Number 9 =	Radar,	Millstone,	#369
Sensor Number 10 =	Radar,	Pirincilik,	#337

Maximum Tracking Capacity --Reduction/New value

Baker-Nunn --- 50% /60 Tracks per day

GEODSS and MOTIF -- 60%/144 Tracks per day

Radars ---25%/60 Tracks per day

num = 9
maxsat = 264
nonsyn = 400
Number of synchronous satellites visible to each sensor

Sensor number	Number of satellites
1	88
2	80
3	77
4	77
5	88
6	125
7	126
8	103
9	78

Combined Deep Space Track Capacity = 2140
Total Deep Space Track Requirement = 796
Total Redundant Track Requirement = 1484

Workload Distribution

Sensor number	No. of Required Tracks	Difference
1	157	203
2	148	212
3	143	217
4	143	-43
5	157	-77
6	202	-122
7	202	-122
8	175	185
9	145	215

overlap visibility array

0	0	55	55	32	83	0	0	11
0	0	19	19	53	0	40	55	0
55	19	0	77	54	50	0	0	0
55	19	77	0	54	50	0	0	0
32	53	54	54	0	27	13	28	0
83	0	50	50	27	0	35	0	53
0	40	0	0	13	35	0	88	60
0	55	0	0	28	0	88	0	22
11	0	0	0	0	53	60	22	0

TABLE 4

MODE 4

Sensor Number 1 =	GEODSS,	Soccoro,	#210
Sensor Number 2 =	GEODSS,	Korea,	#220
Sensor Number 3 =	GEODSS,	Maui,	#230
Sensor Number 4 =	MOTIF,	Maui,	#951
Sensor Number 5 =	Radar,	Altair,	#334
Sensor Number 6 =	Radar,	Millstone,	#369
Sensor Number 7 =	Radar,	Pirincilik,	#337
Sensor Number 8 =	GEODSS,	Diego Garcia,	#240
Sensor Number 9 =	GEODSS,	Portugal,	#250

```
num =  12
maxsat = 264
nonsyn = 400
Number of synchronous satellites visible to each sensor
Sensor number       Number of satellites

     1                        91

     2                        93

     3                        83

     4                        88

     5                        80

     6                        77

     7                        77

     8                        88

     9                       125

    10                       126

    11                       103

    12                        78
Combined Deep Space Track Capacity =  2500
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1802

Workload Distribution
Sensor number         No. of Required Tracks   Difference
     1                        147                 -27
Sensor number         No. of Required Tracks   Difference
     2                        150                 -30
Sensor number         No. of Required Tracks   Difference
     3                        138                 -18
Sensor number         No. of Required Tracks   Difference
     4                        144                 216
Sensor number         No. of Required Tracks   Difference
     5                        135                 225
Sensor number         No. of Required Tracks   Difference
     6                        130                 230
Sensor number         No. of Required Tracks   Difference
     7                        130                 -30
Sensor number         No. of Required Tracks   Difference
     8                        144                 -64
Sensor number         No. of Required Tracks   Difference
     9                        189                -109
Sensor number         No. of Required Tracks   Difference
    10                        189                -109
Sensor number         No. of Required Tracks   Difference
    11                        162                 198
Sensor number         No. of Required Tracks   Difference
    12                        132                 228

overlap visibility array
     0   30   51   58    0   25   25    2   91   26    0   44
    30    0    0    0    3    0    0    0   39   89   51   64
    51    0    0   81    0   57   57   34   76    0    0    4
    58    0   81    0    0   55   55   32   83    0    0   11
     0    3    0    0    0   19   19   53    0   40   55    0
    25    0   57   55   19    0   77   54   50    0    0    0
    25    0   57   55   19   77    0   54   50    0    0    0
     2    0   34   32   53   54   54    0   27   13   28    0
    91   39   76   83    0   50   50   27    0   35    0   53
    26   89    0    0   40    0    0   13   35    0   88   60
     0   51    0    0   55    0    0   28    0   88    0   22
    44   64    4   11    0    0    0    0   53   60   22    0
```

TABLE 3

MODE 3

Sensor Number	1	=	Baker-Nunn,	St Margarets,	# 27
Sensor Number	2	=	Baker-Nunn,	San Vito,	# 25
Sensor Number	3	=	Baker-Nunn,	Edwards,	# 30
Sensor Number	4	=	GEODSS,	Soccoro,	#210
Sensor Number	5	=	GEODSS,	Korea,	#220
Sensor Number	6	=	GEODSS,	Maui,	#230
Sensor Number	7	=	MOTIF,	Maui,	#951
Sensor Number	8	=	Radar,	Altair,	#334
Sensor Number	9	=	Radar,	Millstone,	#369
Sensor Number	10	=	Radar,	Pirincilik,	#337
Sensor Number	11	=	GEODSS,	Diego Garcia,	#240
Sensor Number	12	=	GEODSS,	Portugal,	#250

```
num =  9
maxsat = 264
nonsyn = 400
Number of synchronous satellites visible to each sensor
Sensor number       Number of satellites

     1                          91

     2                          93

     3                          83

     4                          88

     5                          80

     6                          77

     7                          77

     8                          88

     9                         125
Combined Deep Space Track Capacity =  1700
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1436

Workload Distribution
Sensor number         No. of Required Tracks    Difference
     1                          160                 -40
Sensor number         No. of Required Tracks    Difference
     2                          163                 -43
Sensor number         No. of Required Tracks    Difference
     3                          151                 -31
Sensor number         No. of Required Tracks    Difference
     4                          157                 203
Sensor number         No. of Required Tracks    Difference
     5                          148                 212
Sensor number         No. of Required Tracks    Difference
     6                          143                 217
Sensor number         No. of Required Tracks    Difference
     7                          143                 -43
Sensor number         No. of Required Tracks    Difference
     8                          157                 -77
Sensor number         No. of Required Tracks    Difference
     9                          202                -122

overlap visibility array
     0    30    51    58     0    25    25     2    91
    30     0     0     0     3     0     0     0    39
    51     0     0    81     0    57    57    34    76
    58     0    81     0     0    55    55    32    83
     0     3     0     0     0    19    19    53     0
    25     0    57    55    19     0    77    54    50
    25     0    57    55    19    77     0    54    50
     2     0    34    32    53    54    54     0    27
    91    39    76    83     0    50    50    27     0
```

TABLE 2

MODE 2

Sensor Number 1 =	Baker-Nunn,	St Margarets,	# 27
Sensor Number 2 =	Baker-Nunn,	San Vito,	# 25
Sensor Number 3 =	Baker-Nunn,	Edwards,	# 30
Sensor Number 4 =	GEODSS,	Soccoro,	#210
Sensor Number 5 =	GEODSS,	Korea,	#220
Sensor Number 6 =	GEODSS,	Maui,	#230
Sensor Number 7 =	MOTIF,	Maui,	#951
Sensor Number 8 =	Radar,	Altair,	#334
Sensor Number 9 =	Radar,	Millstone,	#369

num = 10
maxsat = 264
nonsyn = 400

Number of synchronous satellites visible to each sensor

Sensor number	Number of satellites
1	91
2	93
3	83
4	88
5	80
6	77
7	77
8	88
9	125
10	126

Combined Deep Space Track Capacity = 1780
Total Deep Space Track Requirement = 796
Total Redundant Track Requirement = 1586

Workload Distribution

Sensor number	No. of Required Tracks	Difference
1	156	-36
2	159	-39
3	147	-27
4	153	207
5	144	216
6	139	221
7	139	-39
8	153	-73
9	198	-118
10	198	-118

overlap visibility array

0	30	51	58	0	25	25	2	91	26
30	0	0	0	3	0	0	0	39	89
51	0	0	81	0	57	57	34	76	0
58	0	81	0	0	55	55	32	83	0
0	3	0	0	0	19	19	53	0	40
25	0	57	55	19	0	77	54	50	0
25	0	57	55	19	77	0	54	50	0
2	0	34	32	53	54	54	0	27	13
91	39	76	83	0	50	50	27	0	35
26	89	0	0	40	0	0	13	35	0

TABLE 1

MODE 1

Sensor Number 1	=	Baker-Nunn,	St Margarets,	# 27
Sensor Number 2	=	Baker-Nunn,	San Vito,	# 25
Sensor Number 3	=	Baker-Nunn,	Edwards,	# 30
Sensor Number 4	=	GEODSS,	Soccoro,	#210
Sensor Number 5	=	GEODSS,	Korea,	#220
Sensor Number 6	=	GEODSS,	Maui,	#230
Sensor Number 7	=	MOTIF,	Maui,	#951
Sensor Number 8	=	Radar,	Altair,	#334
Sensor Number 9	=	Radar,	Millstone,	#369
Sensor Number 10	=	Radar,	Pirincilik,	#337

can be distributed to sensors with larger tracking capacities as long as there is overlapping coverage between the two sensors.This workload shifting will be further illustrated in the analysis of the data in chapter 4.

Tables 17, 18, and 19 summarize the results of tables 1 through 15.

minimum total deep space tracking requirement. It does not consider any overlapping coverages between adjacent sensors.

7. The next item is the total redundant track requirement for all deep space sensors. This value is larger because it includes redundant tasking due to satellites visible to more than one sensor.

8. The next entry is a table of individual sensor workloads and differences between the workload and the sensors maximum tracking capacity. Again note that the workload includes redundant tasking due to overlapping sensor coverage.

9. The last entry is an array containing the number of synchronous satellites in dual visibility between all possible pairs of sensors used in the particular mode. The sensors are not shown on the array but are arranged as follows. From left to right the columns represent in order the sensors from 1 to "num", where num is the number of sensors used for the mode. The rows are order from top to bottom beginning with sensor number 1 to sensor number "num". The number at the intersection of a particular row and column represents the number of synchronous satellites lying within the area of overlapping coverage of the two sensors represented by the row and column.

It would appear from the initial exposure to the data that the Baker-Nunn cameras, the deep space radars, and the MOTIF optical site are overworked. But these results do not reflect that in the real world situation satellite tasking

TABLE 7

MODE 7

Sensor Number 1 = Baker-Nunn,	St Margarets,	# 27
Sensor Number 2 = Baker-Nunn,	San Vito,	# 25
Sensor Number 3 = Baker-Nunn,	Edwards,	# 30
Sensor Number 4 = GEODSS,	Soccoro,	#210
Sensor Number 5 = GEODSS,	Korea,	#220
Sensor Number 6 = GEODSS,	Maui,	#230
Sensor Number 7 = MOTIF,	Maui,	#951
Sensor Number 8 = Radar,	Altair,	#334
Sensor Number 9 = Radar,	Millstone,	#369
Sensor Number 10 = Radar,	Pirincilik,	#337
Sensor Number 11 = GEODSS,	Diego Garcia,	#240
Sensor Number 12 = GEODSS,	Portugal,	#250

Maximum Tracking Capacity --Reduction/New value

Baker-Nunn --- 50% /60 Tracks per day

GEODSS and MOTIF -- 60%/144 Tracks per day

Radars ---25%/60 Tracks per day

num = 12
maxsat = 264
nonsyn = 400

Number of synchronous satellites visible to each sensor

Sensor number	Number of satellites
1	91
2	93
3	83
4	88
5	80
6	77
7	77
8	88
9	125
10	126
11	103
12	78

Combined Deep Space Track Capacity = 1120
Total Deep Space Track Requirement = 796
Total Redundant Track Requirement = 1802

Workload Distribution

Sensor number	No. of Required Tracks	Difference
1	147	-87
2	150	-90
3	138	-78
4	144	0
5	135	9
6	130	14
7	130	-90
8	144	-84
9	189	-129
10	189	-129
11	162	-18
12	132	12

overlap visibility array

0	30	51	58	0	25	25	2	91	26	0	44
30	0	0	0	3	0	0	0	39	89	51	64
51	0	0	81	0	57	57	34	76	0	0	4
58	0	81	0	0	55	55	32	83	0	0	11
0	3	0	0	0	19	19	53	0	40	55	0
25	0	57	55	19	0	77	54	50	0	0	0
25	0	57	55	19	77	0	54	50	0	0	0
2	0	34	32	53	54	54	0	27	13	28	0
91	39	76	83	0	50	50	27	0	35	0	53
26	89	0	0	40	0	0	13	35	0	88	60
0	51	0	0	55	0	0	28	0	88	0	22
44	64	4	11	0	0	0	0	53	60	22	0

TABLE 8

MODE 8

Sensor Number 1 =	GEODSS,	Soccoro,	#210
Sensor Number 2 =	GEODSS,	Korea,	#220
Sensor Number 3 =	GEODSS,	Maui,	#230
Sensor Number 4 =	MOTIF,	Maui,	#951
Sensor Number 5 =	Radar,	Altair,	#334
Sensor Number 6 =	Radar,	Millstone,	#369
Sensor Number 7 =	Radar,	Pirincilik,	#337
Sensor Number 8 =	GEODSS,	Diego Garcia,	#240
Sensor Number 9 =	GEODSS,	Portugal,	#250

Maximum Tracking Capacity --Reduction/New value

GEODSS and MOTIF -- 60%/144 Tracks per day

Radars ---25%/60 Tracks per day

```
num =  9
maxsat = 264
nonsyn = 400
Number of synchronous satellites visible to each sensor
Sensor number      Number of satellites

     1                          88

     2                          80

     3                          77

     4                          77

     5                          88

     6                         125

     7                         126

     8                         103

     9                          78
Combined Deep Space Track Capacity =  940
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1484

Workload Distribution
Sensor number         No. of Required Tracks    Difference
     1                        157                  -13
Sensor number         No. of Required Tracks    Difference
     2                        148                  -4
Sensor number         No. of Required Tracks    Difference
     3                        143                   1
Sensor number         No. of Required Tracks    Difference
     4                        143                  -103
Sensor number         No. of Required Tracks    Difference
     5                        157                  -97
Sensor number         No. of Required Tracks    Difference
     6                        202                  -142
Sensor number         No. of Required Tracks    Difference
     7                        202                  -142
Sensor number         No. of Required Tracks    Difference
     8                        175                  -31
Sensor number         No. of Required Tracks    Difference
     9                        145                  -1

overlap visibility array
    0    0   55   55   32   83    0    0   11
    0    0   19   19   53    0   40   55    0
   55   19    0   77   54   50    0    0    0
   55   19   77    0   54   50    0    0    0
   32   53   54   54    0   27   13   28    0
   83    0   50   50   27    0   35    0   53
    0   40    0    0   13   35    0   88   60
    0   55    0    0   28    0   88    0   22
   11    0    0    0    0   53   60   22    0
```

TABLE 9

MODE 9

DEEP SPACE RADARS ONLY

Sensor Number 1 = Radar,	Altair,	#334
Sensor Number 2 = Radar,	Millstone,	#369
Sensor Number 3 = Radar,	Pirincilik,	#337

```
num =  3
maxsat = 264
nonsyn = 4ØØ
Number of synchronous satellites visible to each sensor
Sensor number       Number of satellites

     1                          88

     2                          125

     3                          126
Combined Deep Space Track Capacity =  24Ø
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  885

Workload Distribution
Sensor number       No. of Required Tracks   Difference
     1                     264                  -184
Sensor number       No. of Required Tracks   Difference
     2                     3Ø9                  -229
Sensor number       No. of Required Tracks   Difference
     3                     3Ø9                  -229

overlap visibility array
     Ø    27    13
    27     Ø    35
    13    35     Ø
```

TABLE 10

MODE 10

DEEP SPACE RADARS ONLY

Sensor Number 1 = Radar,	Altair,	#334
Sensor Number 2 = Radar,	Millstone,	#369
Sensor Number 3 = Radar,	Pirincilik,	#337

Maximum Tracking Capacity --Reduction/New value

Radars ---25%/60 Tracks per day

```
num =  3
maxsat = 264
nonsyn = 400
Number of synchronous satellites visible to each sensor
Sensor number       Number of satellites

     1                          88

     2                         125

     3                         126
Combined Deep Space Track Capacity =  180
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  885

Workload Distribution
Sensor number        No. of Required Tracks   Difference
     1                         264               -204
Sensor number        No. of Required Tracks   Difference
     2                         309               -249
Sensor number        No. of Required Tracks   Difference
     3                         309               -249

overlap visibility array
    0    27    13
   27     0    35
   13    35     0
```

TABLE 11

MODE 11

Sensor Number 1 =	GEODSS,	Soccoro,	#210
Sensor Number 2 =	GEODSS,	Korea,	#220
Sensor Number 3 =	GEODSS,	Maui,	#230
Sensor Number 4 =	Radar,	Altair,	#334
Sensor Number 5 =	Radar,	Millstone,	#369
Sensor Number 6 =	Radar,	Pirincilik,	#337
Sensor Number 7 =	GEODSS,	Diego Garcia,	#240
Sensor Number 8 =	GEODSS,	Portugal,	#250

Maximum Tracking Capacity --Reduction/New value

GEODSS -- 10%/324 Tracks per day

Radars -- 15%/68 Tracks per day

```
num =  8
maxsat = 264
nonsyn = 4ØØ
Number of synchronous satellites visible to each sensor
Sensor number       Number of satellites

     1                           88

     2                           8Ø

     3                           77

     4                           88

     5                          125

     6                          126

     7                          1Ø3

     8                           78
Combined Deep Space Track Capacity =  1824
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1393

Workload Distribution
Sensor number         No. of Required Tracks    Difference
     1                          165                159
Sensor number         No. of Required Tracks    Difference
     2                          156                168
Sensor number         No. of Required Tracks    Difference
     3                          151                173
Sensor number         No. of Required Tracks    Difference
     4                          165                -97
Sensor number         No. of Required Tracks    Difference
     5                          21Ø               -142
Sensor number         No. of Required Tracks    Difference
     6                          21Ø               -142
Sensor number         No. of Required Tracks    Difference
     7                          183                141
Sensor number         No. of Required Tracks    Difference
     8                          153                171

overlap visibility array
      Ø     Ø    55    32    83     Ø     Ø    11
      Ø     Ø    19    53     Ø    4Ø    55     Ø
     55    19     Ø    54    5Ø     Ø     Ø     Ø
     32    53    54     Ø    27    13    28     Ø
     83     Ø    5Ø    27     Ø    35     Ø    53
      Ø    4Ø     Ø    13    35     Ø    88    6Ø
      Ø    55     Ø    28     Ø    88     Ø    22
     11     Ø     Ø     Ø    53    6Ø    22     Ø
```

TABLE 12

MODE 12

Sensor Number 1 =	GEODSS,	Soccoro,	#210
Sensor Number 2 =	GEODSS,	Korea,	#220
Sensor Number 3 =	GEODSS,	Maui,	#230
Sensor Number 4 =	Radar,	Altair,	#334
Sensor Number 5 =	Radar,	Millstone,	#369
Sensor Number 6 =	Radar,	Pirincilik,	#337
Sensor Number 7 =	GEODSS,	Diego Garcia,	#240
Sensor Number 8 =	GEODSS,	Portugal,	#250

Maximum Tracking Capacity --Reduction/New value

GEODSS -- 20%/288 Tracks per day

Radars -- 15%/68 Tracks per day

```
num =  8
maxsat = 264
nonsyn = 400
Number of synchronous satellites visible to each sensor
Sensor number      Number of satellites

     1                        88

     2                        80

     3                        77

     4                        88

     5                       125

     6                       126

     7                       103

     8                        78
Combined Deep Space Track Capacity =  1644
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1393

Workload Distribution
Sensor number       No. of Required Tracks    Difference
     1                    165                     123
Sensor number       No. of Required Tracks    Difference
     2                    156                     132
Sensor number       No. of Required Tracks    Difference
     3                    151                     137
Sensor number       No. of Required Tracks    Difference
     4                    165                     -97
Sensor number       No. of Required Tracks    Difference
     5                    210                    -142
Sensor number       No. of Required Tracks    Difference
     6                    210                    -142
Sensor number       No. of Required Tracks    Difference
     7                    183                     105
Sensor number       No. of Required Tracks    Difference
     8                    153                     135

overlap visibility array
     0     0    55    32    83     0     0    11
     0     0    19    53     0    40    55     0
    55    19     0    54    50     0     0     0
    32    53    54     0    27    13    28     0
    83     0    50    27     0    35     0    53
     0    40     0    13    35     0    88    60
     0    55     0    28     0    88     0    22
    11     0     0     0    53    60    22     0
```

TABLE 13

MODE 13

Sensor Number 1 =	GEODSS,	Soccoro,	#210
Sensor Number 2 =	GEODSS,	Korea,	#220
Sensor Number 3 =	GEODSS,	Maui,	#230
Sensor Number 4 =	Radar,	Altair,	#334
Sensor Number 5 =	Radar,	Millstone,	#369
Sensor Number 6 =	Radar,	Pirincilik,	#337
Sensor Number 7 =	GEODSS,	Diego Garcia,	#240
Sensor Number 8 =	GEODSS,	Portugal,	#250

Maximum Tracking Capacity --Reduction/New value

GEODSS -- 30%/252 Tracks per day

Radars -- 15%/68 Tracks per day

```
num =  8
maxsat = 264
nonsyn = 4ØØ
Number of synchronous satellites visible to each sensor
Sensor number       Number of satellites

     1                        88

     2                        8Ø

     3                        77

     4                        88

     5                       125

     6                       126

     7                       1Ø3

     8                        78
Combined Deep Space Track Capacity =  1464
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1393

Workload Distribution
Sensor number        No. of Required Tracks    Difference
     1                      165                   87
Sensor number        No. of Required Tracks    Difference
     2                      156                   96
Sensor number        No. of Required Tracks    Difference
     3                      151                  1Ø1
Sensor number        No. of Required Tracks    Difference
     4                      165                  -97
Sensor number        No. of Required Tracks    Difference
     5                      21Ø                 -142
Sensor number        No. of Required Tracks    Difference
     6                      21Ø                 -142
Sensor number        No. of Required Tracks    Difference
     7                      183                   69
Sensor number        No. of Required Tracks    Difference
     8                      153                   99

overlap visibility array
    Ø    Ø   55   32   83    Ø    Ø   11
    Ø    Ø   19   53    Ø   4Ø   55    Ø
   55   19    Ø   54   5Ø    Ø    Ø    Ø
   32   53   54    Ø   27   13   28    Ø
   83    Ø   5Ø   27    Ø   35    Ø   53
    Ø   4Ø    Ø   13   35    Ø   88   6Ø
    Ø   55    Ø   28    Ø   88    Ø   22
   11    Ø    Ø    Ø   53   6Ø   22    Ø
```

Mode 2

As mentioned in chapter 3 the purpose of running mode 2 is to indicate the impact of not having useful data from the Pirincilik deep space radar. Although worldwide coverage is still maintained, the loss of this radar does create a significant deficiency. As might be expected, the remaining sensors will experience an increase in workloads which is indicated by the workload distribution table. A potentially greater impact however is the loss of 24 hour tracking and all weather response offered by the radar. The area not covered by the other two radars from 8 to 91 degrees east longitude is now totally dependant on coverage by optical sensors.

Mode 3

With the addition of the final two GEODSS sites in Diego Garcia and Portugal, mode 3 indicates that any deficiencies in track requirements can be accommodated by the larger workload capacities of the GEODSS sensors. Note that both sensors number 2 and 10 which in mode 1 were unable to transfer tracking overloads can now transfer excess satellite track requirements to both of the final two GEODSS sensors in Diego Garcia and Portugal. This is illustrated by the overlap array. Sensor number 2 (row 2) has 51 and 64 satellites in overlapping coverage with GEODSS Diego Garcia and GEODSS Portugal, respectively. Sensor number 10 (row 10) has 88 and 60 satellites in overlapping coverage with GEODSS Diego Garcia and GEODSS Portugal, respectively.

overlap array is used it is possible to shift workloads from overloaded sensors, such as sensor number 1, to one of two GEODSS sensors. Sensor number 2 has a negative difference of 39 but only has 3 satellites in overlapping coverage with sensor number 5 and no satellites in overlapping coverage with the other two GEODSS sensors. It does, however, have overlapping coverage with sensor number 1 (Baker-Nunn,St Margarets),sensor number 9 (radar, Millstone), and sensor number 10 (radar, Pirincilik); but, the work distribution table indicates that these three sensors are also not capable of tracking all satellites within their coverage (ie. have a negative difference)and are unable to transfer enough to a GEODSS sensor to compensate for tracks transferred by sensor no. 2. If a shift of workload is to occur it would be at the expense of creating an even larger tracking deficiency at one of the latter three sensors. Sensor number 10, although able to transfer 40 satellites to GEODSS sensor number 5 is still left with a tracking deficiency. The impact of this tracking shortage is that not all satellites are tracked as often as required and hence their orbits are calculated with minimal data. Fortunately, this is limited to satellites with low tasking priorities. However, as the population of deep space satellites increases this can be expected to worsen if the present tracking capability is not increased.

TABLE 20

TRACKING ADJUSTMENT
FOR MODE 2

Overloaded Sensors	Receiving Sensors 1	4	5	6	9	New Diff
1		45*		25*		0
2	30		3		11	1
3		31				0
8		23		54		0
9		83		50**		0
Sum of Recv Sensors	30	182	3	129	11	

* These values include the extra 30 tracks transferred to sensor #1 by sensor #2.

** This value includes the extra 11 tracks transferred to sensor #9 by sensor #2.

Mode 1

The results of the Mode 1 run indicate that the minimum tracking requirement (todtr) is well within the total tracking capacity of the present deep space sensors. However, as noted in chapter 3 actual tasking is closer to the total redundant track requirement (redtr) which is 89% of the total tracking capacity.

The table of the workload distribution alone, indicates that the three Baker-Nunn sensors, the three radars, and the MOTIF Maui optical sensor are overwhelmed by tracking requirements. However, when the information in the sensor

plus what ever was transfer to them by sensor no. 2. After completing all sensors with negative differences, the next step is to sum up the additional tracks assigned to each of the GEODSS sensors and check that the additional workload does not exceed the maximum tracking capacity of the GEODSS sensor and thereby changing the original positive difference of the GEODSS sensor to a negative difference (ie. too many tracks were assigned to the GEODSS sensor). If after all track reassignments, all sensors have a positive difference, then the conclusion can be made that the sensor network is capable of supplying the required tracks for the deep space satellites in this mode of operation. The adjusted track requirement and adjusted difference is tabulated in tables 21 and 22. Note that Modes 4 through 10, 14 and 15 are not shown since these modes had negative sums of the "Difference" column.

Although the workload distribution has listed sensor number 7 (MOTIF maui) as a sensor with a negative tasking difference, this sensor will not be considered since in reality this sensor is only tasked for high interest objects since GEODSS Maui is capable of tracking all of the satellites in coverage of MOTIF Maui.

with negative differences.

Sensor number 1 (Baker-Nunn, St Margarets) has a negative difference of -40 tracks, however it has overlapping coverage with GEODSS sensors 4 and 6 (Soccoro and Maui). The number of satellites within the overlapping coverages is 58 and 25 tracks, respectively. Hence, sensor number 1 may transfer up to 83 tracks to the two GEODSS sensors combined. This would easily remove the negative difference for sensor number 1.

Sensor number 2 (Baker-Nunn, San Vito) has a negative difference of -43 tracks. But the overlapping coverage of this sensor only has one GEODSS sensor (sensor number 5, Korea) and only three tracks are transferable to it. Note that sensor number 2 also has coverage with sensor number 1 and recall that sensor number 1 was able to transfer up to 83 tracks but only needed to transfer 40. Also note that sensor number 1 has overlapping coverage with sensor number 9 (radar, Millstone) which must be able to transfer 122 tracks. But sensor number 9 also has overlapping cover with GEODSS sensors number 4 and 6, and can transfer up to 133 tracks to the two sensors combined. So even though it is not possible to directly transfer more than three tracks from sensor 2 to the GEODSS sensors, it is possible to indirectly transfer the additional 40 tracks to the GEODSS sensors by sending tracks to sensor number 1 and 9. To compensate for this extra load sensors 1 and 9 in turn transfer the normal number of tracks to the GEODSS sensors

CHAPTER 4

ANALYSIS OF THE RESULTS

Method of Analysis

There is no unique method for analysis of the results generated in this study. The method used here focuses on the ability to eliminate negative values in the " Difference" column of the "Workload Distribution Table". The goal is to remove all negative differences by shifting the workload to the GEODSS sensors which are not loaded to their maximum. The first step is to sum the values within the difference column of the workload distribution table.(see tables 17, 18, and 19) If the sum is a negative value then it is not possible to completely eliminate negative differences for all of the overloaded sensors. On the other hand a positive sum does not necessarily mean that it is possible to completely remove negative differences for all of the overloaded sensors (mode 1). After it has been determined that the sum of the "Difference" is positive, the next step is to determine how many tracks must be reassigned and to whicn sensors must the reassignment be made to. Ultimately, it is necessary to remove the negative differences by reassigning tracks to one or more of the five GEODSS sites since they are the only sensors with positive differences.

Table 20 illustrates how tracks were transferred for the analysis of Mode 2. After identifying the sensors with negative differences, the overlap visibility array will indicate which sensors can share coverage with the sensors

TABLE 19

SUMMARY OF RESULTS

Modes 11 through 14

Sensor No.	MODES 11 Req Trks	11 Diff	12 Req Trks	12 Diff	13 Req Trks	13 Diff	14 Req Trks	14 Diff
210	165	159	165	123	165	87	165	51
220	156	168	156	132	156	96	156	60
230	151	173	151	137	151	101	151	65
334	165	-97	165	-97	165	-97	165	-97
369	210	-142	210	-142	210	-142	210	-142
337	210	-142	210	-142	210	-142	210	-142
240	183	141	183	105	183	69	183	33
250	153	171	153	135	153	99	153	63
Sum of Diff		431		251		71		-109

TABLE 18

SUMMARY OF RESULTS

Modes 5 through 8

Sensor No.	Mode 5 Req Trks	Mode 5 Diff	Mode 6 Req Trks	Mode 6 Diff	Mode 7 Req Trks	Mode 7 Diff	Mode 8 Req Trks	Mode 8 Diff
27	156	-96	160	-100	147	-87	---	---
25	159	-99	163	-103	150	-90	---	---
30	147	-87	151	-91	138	-78	---	---
210	153	-9	157	-13	144	0	157	-13
220	144	0	148	-4	135	9	148	-4
230	139	5	143	1	130	14	143	1
334	153	-93	157	-97	144	-84	157	-97
369	198	-138	202	-142	189	-129	202	-142
337	198	-138	---	---	189	-129	202	-142
240	---	---	---	---	162	-18	175	-31
250	---	---	---	---	132	12	145	-1
Sum of Diff		-655		-549		-580		-429

TABLE 17

SUMMARY OF RESULTS

Modes 1 through 4

Sensor No.	MODES 1 Req Trks	1 Diff	2 Req Trks	2 Diff	3 Req Trks	3 Diff	4 Req Trks	4 Diff
27	156	-36	160	-40	147	-27	---	---
25	159	-39	163	-43	150	-30	---	---
30	147	-27	151	-31	138	-18	---	---
210	153	207	157	203	144	216	157	203
220	144	216	148	212	135	225	148	212
230	139	221	143	217	130	230	143	217
334	153	-73	157	-77	144	-64	157	-77
369	198	-118	202	-122	189	-109	202	-122
337	198	-118	---	---	189	-109	202	-122
240	---	---	---	---	162	198	175	185
250	---	---	---	---	132	228	145	215
Sum of Diff		233		319		740		668

TABLE 16

Sensor Number	Latitude	Longitude	Western Visibility Limit	Eastern Visibility Limit	Maximum Tracking Capacity
27.00	6.90	294.80	241.00	350.00	120.00
25.00	40.60	17.80	321.00	75.00	120.00
30.00	35.00	242.10	187.00	297.00	120.00
210.00	33.80	253.30	195.00	310.00	360.00
220.00	35.70	128.60	73.00	183.00	360.00
230.00	20.70	203.70	140.00	266.00	360.00
951.00	20.70	203.70	140.00	266.00	100.00
334.00	9.40	167.50	91.00	244.00	80.00
369.00	42.60	288.50	208.00	8.00	80.00
337.00	37.90	40.00	325.00	115.00	80.00
240.00	-8.00	73.00	13.00	133.00	360.00
250.00	40.00	352.00	292.00	52.00	360.00

```
num =  8
maxsat = 264
nonsyn = 4ØØ
Number of synchronous satellites visible to each sensor
Sensor number       Number of satellites

     1                         88

     2                         8Ø

     3                         77

     4                         88

     5                         125

     6                         126

     7                         1Ø3

     8                         78
Combined Deep Space Track Capacity =  11Ø4
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1393

Workload Distribution
Sensor number        No. of Required Tracks    Difference
     1                      165                    13
Sensor number        No. of Required Tracks    Difference
     2                      156                    24
Sensor number        No. of Required Tracks    Difference
     3                      151                    29
Sensor number        No. of Required Tracks    Difference
     4                      165                   -97
Sensor number        No. of Required Tracks    Difference
     5                      21Ø                  -142
Sensor number        No. of Required Tracks    Difference
     6                      21Ø                  -142
Sensor number        No. of Required Tracks    Difference
     7                      183                    -3
Sensor number        No. of Required Tracks    Difference
     8                      153                    27

overlap visibility array
     Ø     Ø    55    32    83     Ø     Ø    11
     Ø     Ø    19    53     Ø    4Ø    55     Ø
    55    19     Ø    54    5Ø     Ø     Ø     Ø
    32    53    54     Ø    27    13    28     Ø
    83     Ø    5Ø    27     Ø    35     Ø    53
     Ø    4Ø     Ø    13    35     Ø    88    6Ø
     Ø    55     Ø    28     Ø    88     Ø    22
    11     Ø     Ø     Ø    53    6Ø    22     Ø
```

TABLE 15

MODE 15

Sensor Number 1 =	GEODSS,	Soccoro,	#210
Sensor Number 2 =	GEODSS,	Korea,	#220
Sensor Number 3 =	GEODSS,	Maui,	#230
Sensor Number 4 =	Radar,	Altair,	#334
Sensor Number 5 =	Radar,	Millstone,	#369
Sensor Number 6 =	Radar,	Pirincilik,	#337
Sensor Number 7 =	GEODSS,	Diego Garcia,	#240
Sensor Number 8 =	GEODSS,	Portugal,	#250

Maximum Tracking Capacity --Reduction/New value

GEODSS -- 50%/180 Tracks per day

Radars -- 15%/68 Tracks per day

```
num =  8
maxsat = 264
nonsyn = 4ØØ
Number of synchronous satellites visible to each sensor
Sensor number      Number of satellites

      1                         88

      2                         8Ø

      3                         77

      4                         88

      5                        125

      6                        126

      7                        1Ø3

      8                         78
Combined Deep Space Track Capacity =  1284
Total Deep Space Track Requirement =  796
Total Redundant Track Requirement =  1393

Workload Distribution
Sensor number        No. of Required Tracks   Difference
      1                        165                51
Sensor number        No. of Required Tracks   Difference
      2                        156                6Ø
Sensor number        No. of Required Tracks   Difference
      3                        151                65
Sensor number        No. of Required Tracks   Difference
      4                        165               -97
Sensor number        No. of Required Tracks   Difference
      5                        21Ø              -142
Sensor number        No. of Required Tracks   Difference
      6                        21Ø              -142
Sensor number        No. of Required Tracks   Difference
      7                        183                33
Sensor number        No. of Required Tracks   Difference
      8                        153                63

overlap visibility array
     Ø     Ø    55    32    83     Ø     Ø    11
     Ø     Ø    19    53     Ø    4Ø    55     Ø
    55    19     Ø    54    5Ø     Ø     Ø     Ø
    32    53    54     Ø    27    13    28     Ø
    83     Ø    5Ø    27     Ø    35     Ø    53
     Ø    4Ø     Ø    13    35     Ø    88    6Ø
     Ø    55     Ø    28     Ø    88     Ø    22
    11     Ø     Ø     Ø    53    6Ø    22     Ø
```

TABLE 14

MODE 14

Sensor Number 1 =	GEODSS,	Soccoro,	#210
Sensor Number 2 =	GEODSS,	Korea,	#220
Sensor Number 3 =	GEODSS,	Maui,	#230
Sensor Number 4 =	Radar,	Altair,	#334
Sensor Number 5 =	Radar,	Millstone,	#369
Sensor Number 6 =	Radar,	Pirincilik,	#337
Sensor Number 7 =	GEODSS,	Diego Garcia,	#240
Sensor Number 8 =	GEODSS,	Portugal,	#250

Maximum Tracking Capacity --Reduction/New value

GEODSS -- 40%/216 Tracks per day

Radars -- 15%/68 Tracks per day

These overlaps more than make up for the negative difference in tracking requirements indicated by the workload distribution table for sensors 1 and 10.

Mode 4

Although the loss of the Baker-Nunn sensors does increase the workload of the remaining sensors, it does not appear to increase the load beyond the tracking capabilities of the network. Note that all of the sensors with negative differences in the workload distribution table can transfer more than enough of the workload to the GEODSS sensor system resulting in the removal of the negative workload difference.

Modes 5 Through 8

As discussed in chapter 3, actual performance of the deep space sensors is well below their maximum capacities. Therefore modes 5 through 8 were run to simulate performances when the tracking capacities are reduced from 25% to 60%.

It is very apparent from the workload distribution tables of modes 5 through 8 that none of the modes are capable of meeting the "Total Redundant Track Requirement". In all cases the "Total Redundant Track Requirement" far exceeds the "Combined Deep Space Tracking Capaci'y". Modes 5 through 8 do however appear to be able to meet the minimum "Total Deep Space Track Requirement". As a consequence of this, satellites, in reality, do not receive the optimum

number of observations for orbit analysis. Satellites must be prioritized to ensure adequate tracking of high interest satellites. Observations on low priority satellites are not taken for several days in some cases. This unfortunately leads to situations of many lost satellites and mis-identified satellites.

Modes 9 and 10

The purpose of the last two runs was not to determine if the three deep space radars were capable of tracking the entire deep space satellite population, but to illustrate the overlapping coverage of the three radars and to show that the deep space tracking network is limited in its ability to provide real time tracking data.

As can be seen by both of the overlap arrays each of the three radars have overlapping coverage with the other two radars. This is essential for continuous coverage and hand-offs of high interest events. The combined tracking capacity of the three radars as calculated in mode 10 (180 tracks) represents approximately 27 percent of the total deep space satellite population when we assume that each satellite will require only one track. However, many events require that the radars obtain maximum data which equates to 6 to 12 tracks. What this means is that the three deep space radars are really at their limit if they are tasked only high interest satellites.

Mode 11 Through 15

The analysis provided by these modes indicates that if the reduction in performance of the radar tracking capacity and of the GEODSS tracking capacity can be maintained at less than 15% and 30%, the sensor network would be able to provide the necessary tracking data for the present population of deep space satellites. When the tracking reduction is increased from 30% to 40% for the GEODSS sites the sum of the "difference" column in the workload distribution table becomes negative which indicates that it is not possible provide the necessary track requirements for all of the deep space satellites.

TABLE 21

SUMMARY OF ANALYSIS

Modes 1 through 4

Sensor No.	Mode 1 Adj Trks	Mode 1 Diff	Mode 2 Adj Trks	Mode 2 Diff	Mode 3 Adj Trks	Mode 3 Diff	Mode 4 Adj Trks	Mode 4 Diff
27	120	0	120	0	120	0	---	---
25	156	-36	119	1	120	0	---	---
30	120	0	120	0	120	0	---	---
210	296	64	308	52	254	106	237	123
220	240	120	182	178	175	185	208	152
230	197	163	272	88	238	122	192	168
334	80	0	80	0	80	0	80	0
369	80	0	80	0	80	0	80	0
337	158	-78	---	---	80	0	80	0
240	---	---	---	---	231	129	245	115
250	---	---	---	---	162	198	207	153
Sum of Diff		233		319		740		668
All Sensors With Pos Diff		no		yes		yes		yes

TABLE 22

SUMMARY OF ANALYSIS

Modes 11 through 13

	MODES								
	11		12		13				
Sensor No.	Adj Trks	Diff	Adj Trks	Diff	Adj Trks	Diff			
210	255	69	255	33	245	7			
220	218	106	231	57	231	21			
230	221	103	223	65	228	24			
334	65	3	68	0	68	0			
369	68	0	68	0	68	0			
337	68	0	68	0	68	0			
240	253	71	243	45	243	9			
250	245	79	237	51	242	10			
Sum of Diff		431		251		71			
All Sensors With Pos Diff		yes		yes		yes			

FIGURE 1

PRESENT DEEP SPACE SENSOR COVERAGE

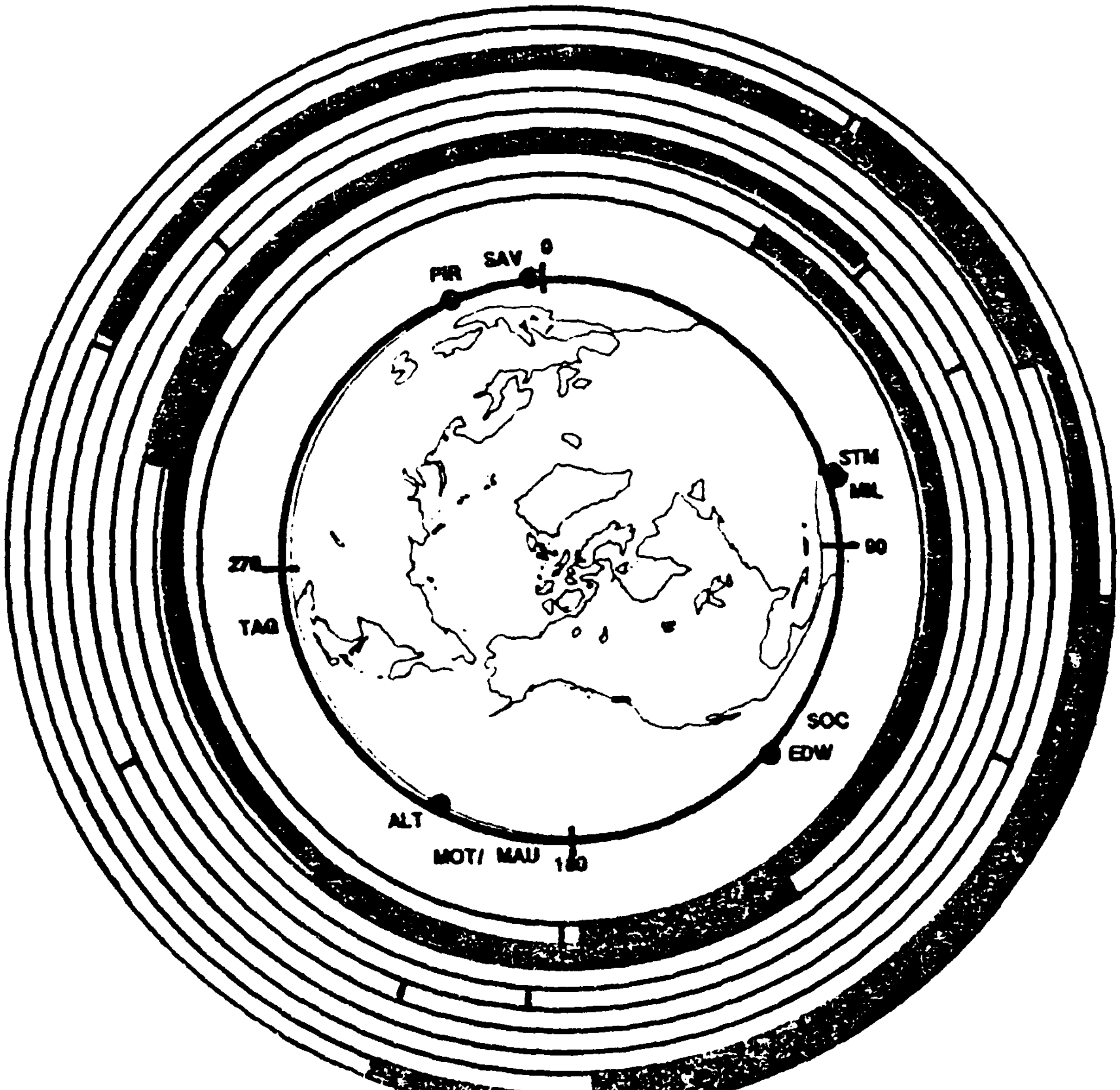
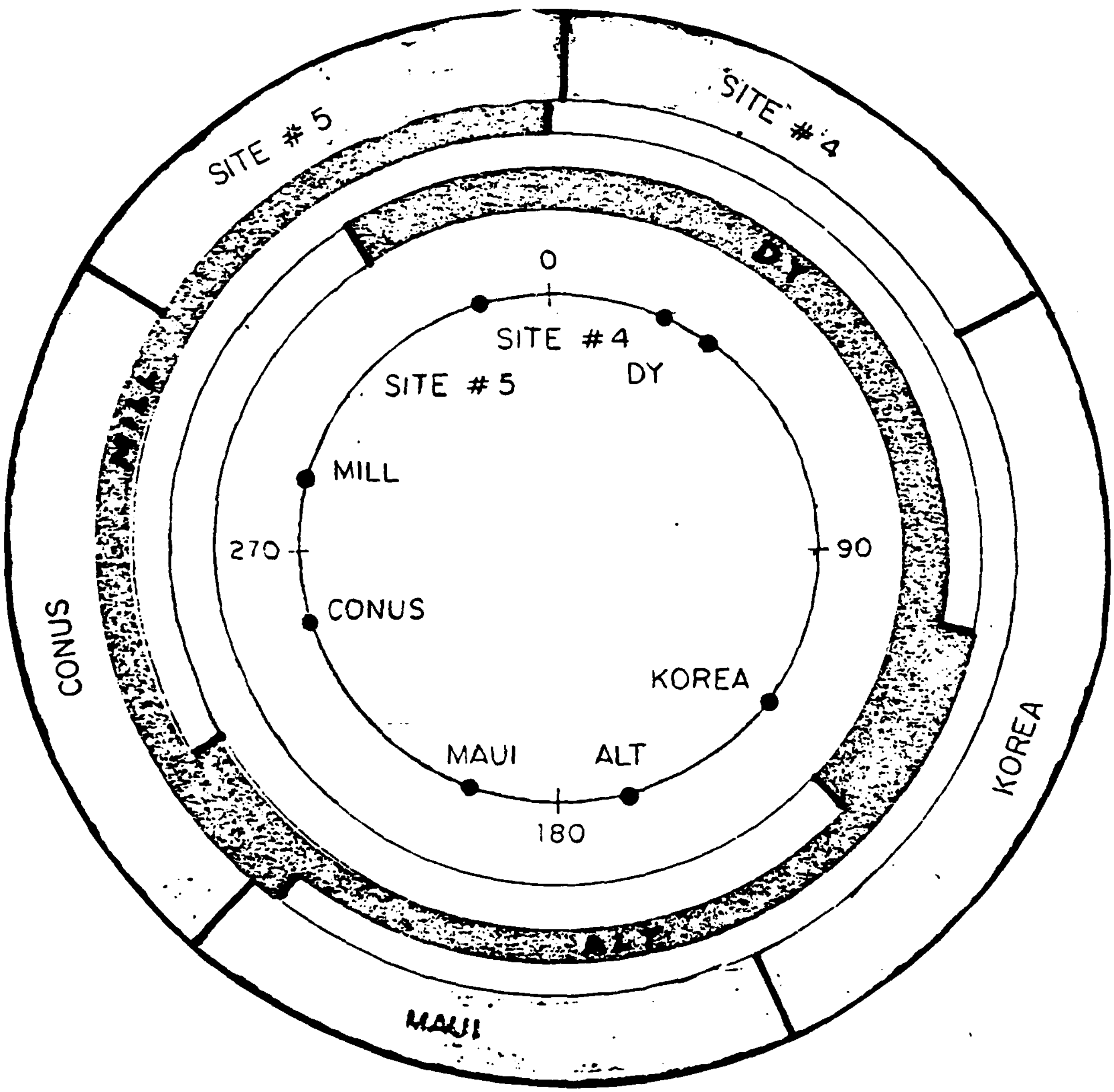


FIGURE 2

DEEP SPACE SENSOR COVERAGE WITH 5 GEODSS SENSORS



Sensor Coverage

Figure 1 illustrates the equatorial coverage of the deep space sensors as described by mode 1. Figure 2 illustrates the coverage as described by mode 4. It is quite clear that in both configurations there is optical sensor overlap as well as radar sensor overlap. The question therefore is not one of physical orbit coverage, but , one of capacity of coverage. As illustrated by the computer runs, the limiting factor is one of more satellites than what the sensors are currently capable of tracking. The mode 11 through 15 results indicate that if the mode 4 performance of the GEODSS sensors is only decreased by 30% and the radars are only decreased by 15% the configuration would be able to adequately able to track the present population of satellites.

The next issue is that of sensor coverage as it relates to the sensor network's ability to respond to realtime events. If an event occurs in an area where the optical sensors are in darkness and in clear weather than coverage would be good as long as the respective radar is also in operation. However, if either the radar or the optical sensor is inoperable, than our ability to track an event becomes limited. Obviously the optical sites would have to be concerned with darkness, weather, and lunar conditions. The radar would not have these concerns but because of the limited deep space search capabilities of the radars,

aquisition of the target may be difficult without the assistence of other sensors.

The other concern is that neither the Altair radar nor the Pirincilik radar are dedicated deep space radars. Hence, there is always competition for radar tracking time. The ideal deep space sensor network should have dedicated sensors at a minimum. In addition, since the present radars are limited in their tracking capacities, research should be accomplished to determine the best means of providing greater tracking capacities. This could mean the construction of more radars or improvements to existing radars.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

The exploitation of space for commercial and military use has increased the importance of maintaining a current catalog of all man-made satellites. This thesis focuses on the deep space tracking network. Because deep space satellites move at a slower angular velocity relative to the near earth satellites, they are visible to fewer sensors. As a result, their orbits are calculated with less data.

Presently, all deep space satellite tracking is performed by a network of three Baker-Nunn cameras, four electro-optical sensors, and three deep space radars. By 1988 two more electro-optical sensors are planned to be operational. These last two sensors will signal the end for the three remaining Baker-Nunn cameras.

The purpose of this thesis effort is to study the tracking workload of the deep space sensors. It will also evaluate the effect of the final two GEODSS sensors as well as the impact of closing down the three Baker-Nunn cameras. Although there is concern of the growth of the deep space satellite population, this study evaluated the deep space sensor network with respect to the present population of satellites.

The heart of this study was the developement of a Fortran program which would detemine sensor visibilities, workloads, and overlapping coverages. After this task was

accomplished, the remaining task was to apply this program to various sensor configurations and analyze the data.

The results indicated that the major factor influencing the performance of the sensors was the maximum tracking capacity and location of the GEODSS sensors. Given ideal tracking conditions, the five GEODSS sensors are capable of handling routine tracking requirements well into the 22nd century. However, present sensor statistics obtained from NORAD show that the GEODSS sensors are operating at 40% of their maximum capability. This of course is due to uncontrollable environmental conditions that the optical sensors must contend with. Although the deep space radars alone are capable of providing worldwide coverage, their limited tracking capacities restrict their use and therefore limit our capablities to respond to realworld events in a realtime fashion.

Conclusions

The proposed deep space sensor network of 5 GEODSS sites and 3 deep space radars has the potential for providing adequate tracking requirements if the following problems are resolved:

1. At a minimum the performance of the GEODSS sensors must be increased by 30%.
2. The three deep space radars must be dedicated deep space radars. As an alternate, 3 new additional radars placed such that they bisect the coverage of the three existing radars can

be acquired. This configuration would enable the deep space network to respond to all realtime events.

3. An additional study should be made into giving the GEODSS sensors a capability of 24 hour operation. One method might use Long Wave Infra-Red.

Recommendations For Further Thesis Research

Additional research into the following areas would provide useful information for further analysis of the deep space satellite tracking network.

1. Application of this program to an estimated deep space population of the 22nd century.
2. Improvement of this program to use actual positional information for the non-synchronous satellites.
3. Application of the program to a sensor network with several more proposed new deep space sensors.
4. Development of a subroutine to account for overlapping coverage with respect to the non-synchronous satellites.

BIBLIOGRAPHY

1. Ageloff, Roy and Mojena, Richard. Applied Fortran 77 Belmont: Wadsworth Publishing Company, 1981.

2. Chobotov, Vladimir A., "Collision Hazard in Space", Astonautics & Aeronautics, Vol 18, Sept. 1980, pp. 38-39.

3. Edelson, Burton I. and Morgan, Walter L., "Orbital Antenna Farms", Astronautics & Aeronautics, Sept. 1977, pp.20-28

4. Hechler, Martin and Van der Ha, Jozef C., "Probability of Collisions in the Geostationary Ring", J. Spacecraft, No.4 July-August 1981, pp. 361-366.

5. Marsh, Peter and Naraine, Mahindra, "Satellites Jostle for Space", News Scientist, 9 June 1983, pp. 707-711.

6. Meyer, Deborah G., "Strategic Satellites: Our Eyes in the Sky, Can They Save the World from Armageddon?, Armed Forces Journal International, Feb.1983, pp. 30-40.

7. Russell, David, M., "NORAD Adds Radar, Optics to Increase Space Defense",Defense Electronics, July 1982, pp. 82-86

8. Staff, "Space Survelillance Deemed Inadequate", Aviation Week & Space Technology, 16 June 1980, pp. 249-259.

9. Staff, "Man-Made Objects in Space", Spaceflight, Jun 1977, pp. 410-413.

10. Talarico, Paul, Capt. USAF, Chief Deep Space Analyst, Telephone interview. Cheyenne Mountain Complex, Colorado Springs, Colorado, 10 Jan 1984.

11. Department of the Air Force. Deep Space Technical Training Guide, Space Command; Directorate of Training SPADOC Division, 1 March 1983.

APPENDIX A

FORTRAN PROGRAM

AD-A151 700 A FORTRAN PROGRAM FOR DEEP SPACE SENSOR ANALYSIS(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING G K HASEGAWA 14 DEC 84 AFIT/GSO/OS/84D-5 2/2

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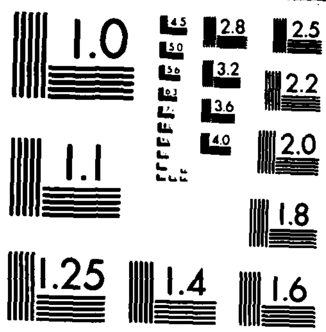

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
*********************************************************************
*********************************************************************
*********************************************************************
*main module name dssnef (DS SENSOR EFFICIENCY)
*
*CLASS: GSO 84D  THESIS          ADVISOR: LTC MEKARU       DATE:26 Oct 84
*NAME OF PROGRAMER: Glenn K Hasegawa   (LOGIN NAME: ghasegaw)
*
*********************************************************************
*
*MODULE DISCRIPTION     Given the synchronous satellite distribution,
*                       along with the total deep space satellite
*                       population, this program will determine the
*                       workload of a specified number of deep space
*                       sensors at specified locations.
*********************************************************************
*
*PROGRAM VARIABLES
*  Type: Real
*       synsat(300,2)            matrix containing the distribution of
*                                synchronous satellites
*
*       sensor(15,10)            matrix containing sensor location,
*                                synchronous longitudinal visibility
*                                limits, and maximum tracking capacities.
*
*       hp                       percentage of synchronous satellites
*                                which have high priority
*
*       np                       percentage of synchronous satellites
*                                which do not have high priority
*
*       hpns                     percentage of non-synchronous satellites
*                                which have high priority
*
*       npns                     percentage of non-synchronous satellites
*                                which do not have high priority
*  Type: Integer
*       i,j                      matrix row and column count
*
*       vissat(15,3)             matrix containing the number of satellites
*                                visible to a sensor
*
*       num                      number of deep space sensors
*
*       hpsrt(15,2)              matrix containing the number of tracks
*                                required on the high priority synchronous
*                                satellites per sensor
*
*       npsrt(15,2)              matrix containing the number of tracks
*                                required on the non-priority synchronous
*                                satellites per sensor
*
*       wortr                    total track requirement for all synchronous
*                                satellites
*
*       nonsyn                   total number of non-synchronous satellites
*
*       nsyvis                   number of non-synchronous satellites
*                                visible per sensor
*
*       tonstr                   total worldwide non-synchronous track
*                                requirement
```

```
*
*       totstr(15,2)            synchronous track requirement per sensor
*
*       maxsat                  maximum number of synchronous satellites
*
*       diff                    difference between total deep space
*                               tracking capacity and total deep space
*                               tracking requirement
*
*       dsscap                  combined deep space sensor track capacity
*
*       wkld(15,2)              tracking requirement per sensor
*
*       todtr                   total deep space tracking requirement
*
*       a,b                     matrix row and column count
*
*       nstrsn                  non-synchronous satellite tracking
*                               requirement per sensor
*
*       ovlp(2Ø,2Ø)             array containing the number of satelllites
*                               visible to two sensors and the respective
*                               sensors
*
*       syntot                  Total system track requirement base on
*                               total satellite population, and accounting
*                               for sensor overlapping coverage.This track
*                               requirement is for synchronous satellites
*                               only.
*
*       redtr                   Redundant tracking requirement for all deep
*                               space satellites.  Includes tracking due
*
*************************************************************************
*
*ALGORITHM DEVELOPMENT
*       MAIN MODULE DSSNEF
*       read in the number of deep space sensors to be used
*       read in the number of synchronous satellites in file
*       read in the number of non-synchronous satellites
*       print the number of deep space sensors
*       print the number of synchronous satellites in file
*       print the number of non-synchronous satellites
*       start do loop
*               read in the synchronous satellite matrix
*       end do loop
*       start do loop
*               print the synchronous satellite matrix
*       end do loop
*       start do loop
*               read in the sensor matrix
*       end do loop
*       start do loop
*               print sensor matrix
*       end do loop
*       call subroutine synvis
*       call subroutine synctr
*       call subroutine nsynvi
*       call subroutine nsyntr
*       call subroutine todstr
*       call subroutine wordis
*       call subroutine ovrlap
*       call subroutine print
*       end main module
```

```
************************************************************************
c       start main module
        program dssnef
c-----------------------------------------------------------------------
c       variable table
        real synsat(3ØØ,2), sensor(15,1Ø),hp,np,hpns,npns
        integer i,j,vissat(15,3),num,hpsrt(15,2),npsrt(15,2),wortr,redtr
        integer nonsyn,nsyvis,nsyvis,tonstr,totstr(15,2),ovlp(2Ø,2Ø)
        integer maxsat,diff,dsscap,wkld(15,3),todtr,a,b,nstrsn,syntot
c-----------------------------------------------------------------------
        read*,num
        read*,maxsat
        read*,nonsyn
        print*,'num = ',num
        print*,'maxsat =',maxsat
        print*,'nonsyn =',nonsyn
        do 2 i = 1,maxsat
                        read*,(synsat(i,j),j = 1,2)
 2      continue
*       do 5 a = 1,maxsat
*               print*
*               print 7,(synsat(a,b),b = 1,2)
* 7             format (' ',6F15.2)
* 5     continue
        do 4 i = 1,num
                read*,(sensor(i,j),j = 1,6)
 4      continue
        do 8 a = 1,num
                print*
                print 9,(sensor(a,b),b = 1,6)
 9              format (' ',6F1Ø.2)
 8      continue
        call synvis(vissat,num,synsat,sensor,maxsat)
        call synctr(vissat,hp,np,hpsrt,npsrt,totstr,wortr,num,maxsat,syntot
        call nsynvi(num,nonsyn,nsyvis)
        call nsyntr(hpns,npns,nsyvis,tonstr,num,nstrsn,nonsyn)
        call todstr(sensor,tonstr,syntot,num,diff,todtr,dsscap,redtr,wortr)
        call wordis(wkld,num,sensor,nstrsn,totstr)
        call ovrlap(num,synsat,sensor,maxsat,ovlp)
        call print(vissat,dsscap,todtr,num,wkld,ovlp,redtr)
        end
c       end main module
c-----------------------------------------------------------------------
************************************************************************
************************************************************************
************************************************************************
*
*subroutine synvis
************************************************************************
*
*MODULE DESCRIPTION:    This module will determine the number of
*                       synchronous satellites visible to each sensor
*
************************************************************************
*LOCAL VARIABLES
*  Type: Integer
*       lwlim           lower sensor synchronous longitudinal visibility
*                       limit
*
*       uplim           upper sensor synchronous longitudinal visibility
*                       limit
*
*       n               satellite counter
*
```

```
*       losatn          lower limit satellite number
*
*       hisatn          upper limit satellite number
*
*       t               satellite counter
*
*       k               sensor counter
*
*       sum             number of synchronous satellites visible to sensor
*
***************************************************************************
*ALGORITHM DEVELOPMENT
*
*       start subroutine synvis
*       start do loop
*               print blank line
*               print value of counter 'k'
*               assign to variable lwlim value stored in matrix sensor(k,4)
*               print value of sensor(k,4)
*               assign to variable uplim value stored in matrix sensor(k,5)
*               print value of sensor(k,5)
*               locate nearest satellite at lower limit
*               if (lwlim > synsat(n,2)) then
*                       n = n + 1
*                       repeat until condition is not met
*               end if
*               satellite  nearest lower sensor visibility limit is 'n'
*               assign to variable losatn the value of n
*               print the value of losatn
*               locate nearest satellite at upper limit
*               starting at t equal value of maxsat
*               if (uplim < synsat(t,2) then
*                       t = t - 1
*                       repeat until condition is not met
*               end if
*               satellite nearest upper sensor visibility limit is 't'
*               assign to variable hisatn the value of t
*               print the value of hisatn
*               determine the number of satellites between the longitude
*                       limits
*                       variable maxsat equals the maximum number of
*                               synchronous satellites
*                       number of visible satellites equals the
*                               difference between hisatn and losatn
*                               unless the difference is negative, then
*                               it equals the value of hisatn plus the
*                               difference between the values of maxsat
*                               and losatn
*                       assign to array(k,2) the calculated number of
*                               visible satellites
*               print sensor number
*               print the number of visible satellites
*       end do loop
*       end subroutine synvis
***************************************************************************
c       start subroutine synvis
        subroutine synvis(vissat,num,synsat,sensor,maxsat)
c--------------------------------------------------------------------------
        real synsat(300,2),sensor(15,10)
        integer vissat(15,3),num,lwlim
        integer uplim,n,losatn,hisatn,t,ma sat,k,sum
c--------------------------------------------------------------------------
        do 25 k = 1,num
        print*
```

```
        print*,'k = ',k
        lwlim = sensor(k,4)
        print*,'sensor(k,4)=',sensor(k,4)
        uplim = sensor(k,5)
        print*,'sensor(k,5)=',sensor(k,5)
        print*,'lwlim = ',lwlim
        print*,'uplim = ',uplim
c       locate nearest satellite at lower limit
        n = 1
 10     if (lwlim .gt. synsat(n,2)) then
                n = n + 1
                go to 10
        end if
        losatn = n
        print*,'losatn = ',losatn
c       locate nearest satellite at upper limit
        t = 264
 15     if (uplim .lt. synsat(t,2)) then
                t = t - 1
                go to 15
        end if
        hisatn = t
        print*,'hisatn =',hisatn
c       determine the number of satellites between longitude limits
c       maxsat = the total number of synchronous satellites
        sum = hisatn - losatn + 1
        print*,'sum =',sum
        if (sum .lt. 0) then
                sum = 0
                sum = hisatn + (maxsat - losatn + 1)
                vissat(k,2) = sum
                vissat(k,1) = k
        else
                vissat(k,2) = sum
                vissat(k,1) = k
        end if
        print*,'vissat(k,1) =',vissat(k,1)
        print*,'vissat(k,2) =',vissat(k,2)
 25     continue
        end
c       end subroutine synvis
c-----------------------------------------------------------------
*****************************************************************
*****************************************************************
*****************************************************************
*****************************************************************
*subroutine synctr
*       This subroutine will calculate the track requirements for the
*       synchronous satellites visible to each sensor.
*****************************************************************
*
*LOCAL VARIABLES
*  Type: Integer
*       w               sensor counter
*
*       sat             number of satellites visible to a specific sensor
*
*       s               sensor counter
*
*       a               variable holder for hpsrt(s,2)
*
*       b               variable holder for npsrt(s,2)
*
*****************************************************************
```

```
*
*ALGORITHM DEVELOPMENT
*
*       start subroutine synctr
*       set percentage of high priority synchronous satellite
*       set percentage of non-high priority synchronous satellite
*       start do loop
*               print blank line
*               print value of variable s
*               assign to variable sat the value stored in vissat(s,2)
*               calculate the number of required tracks for high priority
*                       synchronous satellites, store in hpsrt(s,2) note high
*                       priority satellites are tracked twice per day minimum
*               print value of hpsrt(s,2)
*               assign to variable a the value stored in hpsrt(s,2)
*               calculate the number of required tracks for non priority
*                       synchronous satellites, store in npsrt(s,2)non-high
*                       priority satellites are tracked once per day
*               print value of npsrt(s,2)
*               assign to variable b the value stored in npsrt(s,2)
*               calculate the total number of tracks required for all
*                       synchronous satellites visible to sensor s
*               print total track requirement, totstr(s,2)
*       end do loop
*       start do loop
*               calculate total track requirement for all synchronous
*               satellites visible to all deep space sensors
*               store value in variable wortr
*       end do loop
*       print total track requirement, wortr
*       calculate total track requirement accounting for sensor overlapping
*               coverage
*       end subroutine synctr
***********************************************************************
c       start subroutine synctr
        subroutine synctr(vissat,hp,np,hpsrt,npsrt,totstr,wortr,num,
     c                          maxsat,syntot)
c----------------------------------------------------------------------
        real hp,np
        integer vissat(15,3),hpsrt(15,2),npsrt(15,2),totstr(15,2)
        integer num,w,sat,wortr,s,a,b,syntot,maxsat
c----------------------------------------------------------------------
        hp = Ø.2
        np = Ø.8
        do 4Ø s = 1,num
        print*
        print*,'s = ',s
        sat = vissat(s,2)
        hpsrt(s,2) = (hp * sat)*2
        print*,'hpsrt(s,2) = ',hpsrt(s,2)
        a = hpsrt(s,2)
        npsrt(s,2) = (np * sat)*1
        print*,'npsrt(s,2) = ',npsrt(s,2)
        b = npsrt(s,2)
        totstr(s,2) =  a + b
        print*,'totstr(s,2) = ',totstr(s,2)
 4Ø     continue
c       worldwide synchronous track requirement
        wortr = Ø
        do 45 w = 1,num
                wortr = totstr(w,2) + wortr
 45     continue
        print*
        print*,'wortr =',wortr
```

```
        syntot = (hp*maxsat)*2 + (np*maxsat)
        end
c       end subroutine synctr
c-----------------------------------------------------------------------
************************************************************************
************************************************************************
************************************************************************
*subroutine nsynvi
*       This subroutine will calculate the number of non-synchronous
*       satellites visable to a sensor.
************************************************************************
*
*ALGORITHM DEVELOPEMENT
*
*       start subroutine nsynvi
*       calculate the number of non-synchronous satellites visible to
*               each sensor, store value in nsyvis
*       print value of nsyvis
*       end subroutine nsynvi
************************************************************************
c       start subroutine nsynvi
        subroutine nsynvi(num,nonsyn,nsyvis)
c-----------------------------------------------------------------------
        integer num,nonsyn,nsyvis
c-----------------------------------------------------------------------
c       calculate number of nonsync satellites visable per sensor
        nsyvis = Ø
        nsyvis = nonsyn/num
        print*,'nsyvis =',nsyvis
        end
c       end subroutine nsyvis
c-----------------------------------------------------------------------
************************************************************************
************************************************************************
************************************************************************
*subroutine nsyntr
*       This subroutine will determine the number of tracks required on
*       the non-synchronous satellites visible to each sensor.
************************************************************************
*
*LOCAL VARIABLES
*  Type: Integer
*       hpnstr          number of high priority tracks required per
*                       sensor on non-synchronous satellites
*
*       npnstr          number of non-priority tracks required per
*                       sensor on non-synchronous satellites
*
************************************************************************
*
*ALGORITHM DEVELOPEMENT
*
*       start subroutine nsyntr
*       set percentage of high priority non-synchronous satellites
*       set percentage of non priority non-synchronous satellites
*       calculate the number of tracks required for high priorit non-
*               synchronous satellites, store value in hpnstr note this
*               is tracks required per sensor also high priority satellites
*               are tracked a minimum of twice per day
*       calculate the number of tracks required for non priority non-
*               synchronous satellites, store value in npnstr note, this
*               is tracks required per sensor, also these satellites are
*               tracked only once per day
*       calculate the total track requirement per sensor for non-synchronous
```

```
*               satellites, store this value in variable nstrsn
*    .    print value of nstrsn
*         calculate worldwide track requirement for non-synchronous satellites
*               store this value in variable tonstr
*         end of subroutine nsyntr
**************************************************************************
c         start subroutine nsyntr
          subroutine nsyntr(hpns,npns,nsyvis,tonstr,num,nstrsn,nonsyn)
c-----------------------------------------------------------------------
          real hpns,npns
          integer hpnstr,npnstr,nsyvis,tonstr,num,nstrsn,nonsyn
c-----------------------------------------------------------------------
          hpns = Ø.2
          npns = Ø.8
          hpnstr = (hpns*nsyvis)*2
          npnstr = (npns * nsyvis)*1
          nstrsn = hpnstr + npnstr
          print*,'nstrsn =',nstrsn
          tonstr = (nonsyn*hpns)*2 + (nonsyn*npns)
          print*,'tonstr =',tonstr
          end
c         end subroutine nsyntr
************************************************************************
************************************************************************
************************************************************************
*subroutine todstr
*         This subroutine will determine the total deep space satellite
*         track requirement and determine the difference between this
*         requirement and the sensor track capacity.
************************************************************************
*
*LOCAL VARIABLES
*  Type: Integer
*         m                    sensor counter
*
************************************************************************
*
*ALGORITHM DEVELOPEMENT
*
*         start subroutine todstr
*         calculate total deep space track requirement for all deep space
*               satellites for all deep space sensors
*               store in variable todtr
*         print value of todtr
*         start do loop
*               calculate total deep space sensor tracking capacity
*               store value in variable dsscap
*         end do loop
*         print value of dsscap
*         calculate difference between total tracking capacity of all
*               deep space sensors and the total track requirement
*               store this value in variable diff
*         print value of diff
*         end of subroutine todstr
************************************************************************
c         start subroutine todstr
          subroutine todstr(sensor,tonstr,syntot,num,diff,todtr,dsscap,
     c    redtr,wortr)
c-----------------------------------------------------------------------
          integer tonstr,syntot,num,diff,dsscap,todtr,m,redtr,wortr
          real sensor(15,6)
c-----------------------------------------------------------------------
          todtr = Ø
          todtr = tonstr + syntot
```

```
        redtr = tonstr + wortr
        print*,'redtr = ',redtr
        print*,'todtr = ',todtr
c       calculate deep space combine sensor track capacity
        dsscap = 0
        do 60 m = 1,num
                dsscap = dsscap + sensor(m,6)
 60     continue
        print*,'dsscap = ',dsscap
c       difference in capacity and requirement calculation
        diff = dsscap - todtr
        print*,'diff = ',diff
        print*,'todtr = ',todtr
        end
c       end subroutine todstr
c-----------------------------------------------------------------------
************************************************************************
************************************************************************
************************************************************************
*subroutine wordis
*       This subroutine will determine the workload distribution for
*       each individual  sensor.
************************************************************************
*
*LOCAL VARIABLES
*  Type: Integer
*       p               sensor counter
*
*       a               variable holder for sensor max tracking capacity
*
*       b               variable holder for sensor tracking requirement
*
************************************************************************
*
*ALGORITHM DEVELOPEMENT
*
*       start subroutine wordis
*       start do loop
*               calculate tracking workload for all satellite types
*               per sensor, store valued in matrix wkld(p,2)
*               assign to variable a the max tracking capacity for
*                       sensor p, where p is the sensor number
*               assign to variable b the tracking requirement for
*                       sensor p
*               determine the difference between the max capacity and
*                       tracking requirement, store value in wkld(p,3)
*               print value of wkld(p,2)
*               print value of wkld(p,3)
*       end do loop
*       end subroutine wordis
************************************************************************e
c       start subroutine wordis
        subroutine wordis(wkld,num,sensor,nstrsn,totstr)
c-----------------------------------------------------------------------
        integer wkld(15,3),num,nstrsn,p,totstr(15,2),a,b
        real sensor(15,10)
c-----------------------------------------------------------------------
        do 80 p = 1,num
                wkld(p,2) = totstr(p,2) + nstrsn
                wkld(p,1) = p
                a = sensor(p,6)
                b = wkld(p,2)
                wkld(p,3) = a - b
                print*,'wkld(p,2) = ',wkld(p,2)
```

```
                print*,'wkld(p,3) = ',wkld(p,3)
 80     continue
        end
c       end subroutine wordis
c-------------------------------------------------------------------
*******************************************************************
*******************************************************************
*******************************************************************
*
*subroutine ovrlap
*       This subroutine will determine the if two adjacent sensors have
*       overlapping coverage.  If there is overlapping coverage, then
*       the number of synchronous satellites in the overlapping coverage
*       will be calculated.
*******************************************************************
*
*LOCAL VARIABLES
*  Type: Integer
*       lwbord              lower synchronous longitudinal visibility limit
*                           of secondary sensor whose visibility coverage
*                           is being tested for overlap with the primary
*                           sensor.
*
*       upbord              upper synchronous longitudinal visibility limit
*                           of secondary sensor whose visibility coverage
*                           is being tested for overlap with the primary
*                           sensor.
*
*       low                 variable representing the lower longitude bound
*                           of the overlap coverage
*
*       high                variable representing the upper longitude bound
*                           of the overlap coverage
*
*       t                   satellite counter
*
*       k                   sensor counter
*
*       b                   sensor counter
*
*       h                   variable representing (uplim - 360)
*
*       lwlim,uplim
*       losatn,hisatn
*       sum                 see subroutine synvis
*
*******************************************************************
*
*ALGORITHM DEVELOPMENT
*
*       start subroutine ovrlap
*       start outer do loop
*               assign to variable "lwlim" the value stored in matrix
*                       sensor(k,4) of primary sensor
*               assign to variable "uplim" the value stored in matrix
*                       sensor(k,5) of primary sensor
*               start inner do loop
*                       assign to variable "lwbord" the value stored in
*                               matrix sensor(b,4) of secondary sensor
*                       assign to variable "upbord" the value stored in
*                               matrix sensor(b,5) of secondary sensor
*                       set value of variables "n" and "t" to 0
*                       account for sensors whose coverage straddles the
*                               prime meridian
```

```
*                               if (uplim < lwlim) then
*                               uplim = uplim + 36Ø
*                               if (upbord < lwbord) then
*                               upbord = upboard + 36Ø
*                       if (uplim > lwbord > lwlim ) then
*                               n = 1
*                               locate nearest satellite at lower limit
*                               if ( lwbord > synsat(n,2)) then
*                                       n = n + 1
*                                       repeat until condition is not met
*                               end if
*                               satellite nearest lower sensor visibility
*                                       limit is 'n'
*                               assign to variable losatn the value of 'n'
*                               assign to variable "t" the value of "maxsat"
*                               locate nearest satellite at upper limit
*                               if (uplim < synsat(t,2)) then
*                                       t = t - 1
*                                       repeat until condition is not met
*                               end if
*                               satellite nearest upper sensor visibility
*                                       limit is 't'
*                               assign to variable hisatn the value of 't'
*                               print longitude limits of overlapping
*                                       coverage
*                       end if
*                       if (lwlim < upbord < uplim ) t
*                               n = 1
*                               locate nearest satellite at lower limit
*                               if (lwlim > synsat(n,2)) the
*                                       n = n + 1
*                                       repeat until condition is not met
*                               end if
*                               satellite nearest lower sensor visibility
*                                       limit is 'n'
*                               assign to variable losatn the value of 'n'
*                               assign to variable "t" the value of "maxsat"
*                               locate nearest satellite at upper limit
*                               if (upbord < synsat(t,2)) then
*                                       t = t - 1
*                                       repeat until condition is not met
*                               end if
*                               satellite nearest upper sensor visibility
*                                       limit is 't'
*                               assign to variable hisatn the value of 't'
*                               print longitude limits of overlapping
*                                       coverage
*                       end if
*                       if ( n does not = Ø and t does not = Ø) then
*                               determine the number of satellites in
*                                       dual coverage
*                               number of visible satellites equals the
*                                       difference between hisatn and losatn
*                                       unless the difference is negative,
*                                       then it equals the value of hisatn
*                                       plus the difference between the
*                                       values of maxsat and losatn
*                               assign to array ovlp(2Ø,2Ø) the calculated
*                                       number of visible satellites
*                       end if
*                       print the number of satellites in dual coverage of
*                               sensor numbers k and b
*               end if
*               continue inner loop
```

```
*       continue outer loop
*       end subroutine ovrlap
*********************************************************************
********************************************************************
c       start subroutine ovrlap
        subroutine ovrlap(num,synsat,sensor,maxsat,ovlp)
c--------------------------------------------------------------------
        real synsat(3ØØ,2),sensor(15,1Ø)
        integer num,lwlim,uplim,lwbord,upbord,t,k,sum,ovlp(2Ø,2Ø)
        integer maxsat,b,hisatn,losatn,n,low,high,h
c--------------------------------------------------------------------
        do 13Ø k = 1,num
                lwlim = sensor(k,4)
                uplim = sensor(k,5)
                do 14Ø b = 1,num
                        lwbord = sensor(b,4)
                        upbord = sensor(b,5)
                        n = Ø
                        t = Ø
                        if (upbord .gt. lwlim .and. upbord .lt. uplim) then
                                n = 1
                                low = lwlim
                                high = upbord
 144                            if (low .gt. synsat(n,2)) then
                                        n = n + 1
                                        go to 144
                                end if
                                losatn = n
                                t = maxsat
 148                            if (high .lt. synsat(t,2)) then
                                        t = t - 1
                                        go to 148
                                end if
                                hisatn = t
                                print*
                                print*,'between',low,'east longitude'
                                print*,'and',high,'east longitude'
                                print*,'sensor no.',k,'and sensor no.',b
                                print*,'have overlapping coverage'
                        end if
                        if (uplim .lt. lwlim) then
                                uplim = 36Ø + uplim
                        end if
                        if (upbord .lt. lwbord) then
                                upbord = upbord + 36Ø
                        end if
                        if (lwbord .lt. uplim .and. lwbord .gt. lwlim) then
                                n = 1
                                low = lwbord
                                high = uplim
                                if ( high .ge. 36Ø) then
                                        high = high - 36Ø
                                end if
 15Ø                            if (low .gt. synsat(n,2)) then
                                        n = n + 1
                                        go to 15Ø
                                end if
                                losatn = n
                                t = maxsat
 16Ø                            if (high .lt. synsat(t,2)) then
                                        t = t - 1
                                        go to 16Ø
                                end if
                                hisatn = t
```

between 195 east longitude
and 266 east longitude
sensor no. 4 and sensor no. 7
have overlapping coverage

between 195 east longitude
and 266 east longitude
sensor no. 4 and sensor no. 7
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 4 and sensor number 7
is 55

between 195 east longitude
and 244 east longitude
sensor no. 4 and sensor no. 8
have overlapping coverage

between 195 east longitude
and 244 east longitude
sensor no. 4 and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 4 and sensor number 8
is 32

between 208 east longitude
and 310 east longitude
sensor no. 4 and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 4 and sensor number 9
is 83

sensor number 4 and
sensor number 10
have no overlapping coverage

sensor number 5 and
sensor number 1
have no overlapping coverage

between 73 east longitude
and 75 east longitude
sensor no. 5 and sensor no. 2
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 5 and sensor number 2
is 3

sensor number 5 and
sensor number 3
have no overlapping coverage

sensor number 5 and
sensor number 4
have no overlapping coverage

sensor number 5 and
sensor number 5

sensor number 3 and sensor number 8
is 34

between 208 east longitude
and 297 east longitude
sensor no. 3 and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 3 and sensor number 9
is 76

sensor number 3 and
sensor number 10
have no overlapping coverage

between 241 east longitude
and 310 east longitude
sensor no. 4 and sensor no. 1
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 4 and sensor number 1
is 58

sensor number 4 and
sensor number 2
have no overlapping coverage

between 195 east longitude
and 297 east longitude
sensor no. 4 and sensor no. 3
have overlapping coverage

between 195 east longitude
and 297 east longitude
sensor no. 4 and sensor no. 3
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 4 and sensor number 3
is 81

sensor number 4 and
sensor number 4
have no overlapping coverage

sensor number 4 and
sensor number 5
have no overlapping coverage

between 195 east longitude
and 266 east longitude
sensor no. 4 and sensor no. 6
have overlapping coverage

between 195 east longitude
and 266 east longitude
sensor no. 4 and sensor no. 6
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 4 and sensor number 6
is 55

the overlapping coverage between
sensor number 3 and sensor number 1
is 51

sensor number 3 and
sensor number 2
have no overlapping coverage

sensor number 3 and
sensor number 3
have no overlapping coverage

between 195 east longitude
and 297 east longitude
sensor no. 3 and sensor no. 4
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 3 and sensor number 4
is 81

sensor number 3 and
sensor number 5
have no overlapping coverage

between 187 east longitude
and 266 east longitude
sensor no. 3 and sensor no. 6
have overlapping coverage

between 187 east longitude
and 266 east longitude
sensor no. 3 and sensor no. 6
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 3 and sensor number 6
is 57

between 187 east longitude
and 266 east longitude
sensor no. 3 and sensor no. 7
have overlapping coverage

between 187 east longitude
and 266 east longitude
sensor no. 3 and sensor no. 7
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 3 and sensor number 7
is 57

between 187 east longitude
and 244 east longitude
sensor no. 3 and sensor no. 8
have overlapping coverage

between 187 east longitude
and 244 east longitude
sensor no. 3 and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between

and 35Ø east longitude
sensor no. 2 and sensor no. 1
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 2 and sensor number 1
is 3Ø

sensor number 2 and
sensor number 2
have no overlapping coverage

sensor number 2 and
sensor number 3
have no overlapping coverage

sensor number 2 and
sensor number 4
have no overlapping coverage

between 73 east longitude
and 75 east longitude
sensor no. 2 and sensor no. 5
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 2 and sensor number 5
is 3

sensor number 2 and
sensor number 6
have no overlapping coverage

sensor number 2 and
sensor number 7
have no overlapping coverage

sensor number 2 and
sensor number 8
have no overlapping coverage

between 321 east longitude
and 8 east longitude
sensor no. 2 and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 2 and sensor number 9
is 39

between 325 east longitude
and 75 east longitude
sensor no. 2 and sensor no. 1Ø
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 2 and sensor number 1Ø
is 89

between 241 east longitude
and 297 east longitude
sensor no. 3 and sensor no. 1
have overlapping coverage
The number of visible satellites in

```
sensor number 5
have no overlapping coverage

between 241 east longitude
and 266 east longitude
sensor no. 1 and sensor no. 6
have overlapping coverage

between 241 east longitude
and 266 east longitude
sensor no. 1 and sensor no. 6
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 6
is 25

between 241 east longitude
and 266 east longitude
sensor no. 1 and sensor no. 7
have overlapping coverage

between 241 east longitude
and 266 east longitude
sensor no. 1 and sensor no. 7
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 7
is 25

between 241 east longitude
and 244 east longitude
sensor no. 1 and sensor no. 8
have overlapping coverage

between 241 east longitude
and 244 east longitude
sensor no. 1 and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 8
is 2

between 241 east longitude
and 350 east longitude
sensor no. 1 and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 9
is 91

between 325 east longitude
and 350 east longitude
sensor no. 1 and sensor no. 10
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 10
is 26

between 321 east longitude
```

```
todtr =  796
wkld(p,2) =  156
wkld(p,3) =  -36
wkld(p,2) =  159
wkld(p,3) =  -39
wkld(p,2) =  147
wkld(p,3) =  -27
wkld(p,2) =  153
wkld(p,3) =  2Ø7
wkld(p,2) =  144
wkld(p,3) =  216
wkld(p,2) =  139
wkld(p,3) =  221
wkld(p,2) =  139
wkld(p,3) =  -39
wkld(p,2) =  153
wkld(p,3) =  -73
wkld(p,2) =  198
wkld(p,3) =  -118
wkld(p,2) =  198
wkld(p,3) =  -118

sensor number 1 and
sensor number 1
have no overlapping coverage

between 321 east longitude
and 35Ø east longitude
sensor no. 1 and sensor no. 2
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 2
is 3Ø

between 241 east longitude
and 297 east longitude
sensor no. 1 and sensor no. 3
have overlapping coverage

between 241 east longitude
and 297 east longitude
sensor no. 1 and sensor no. 3
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 3
is 51

between 241 east longitude
and 31Ø east longitude
sensor no. 1 and sensor no. 4
have overlapping coverage

between 241 east longitude
and 31Ø east longitude
sensor no. 1 and sensor no. 4
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1 and sensor number 4
is 58

sensor number 1 and
```

```
losatn =  234
hisatn = 95
sum = -138
vissat(k,1) = 10
vissat(k,2) = 126

s =  1
hpsrt(s,2) =  36
npsrt(s,2) =  72
totstr(s,2) =  108

s =  2
hpsrt(s,2) =  37
npsrt(s,2) =  74
totstr(s,2) =  111

s =  3
hpsrt(s,2) =  33
npsrt(s,2) =  66
totstr(s,2) =  99

s =  4
hpsrt(s,2) =  35
npsrt(s,2) =  70
totstr(s,2) =  105

s =  5
hpsrt(s,2) =  32
npsrt(s,2) =  64
totstr(s,2) =  96

s =  6
hpsrt(s,2) =  30
npsrt(s,2) =  61
totstr(s,2) =  91

s =  7
hpsrt(s,2) =  30
npsrt(s,2) =  61
totstr(s,2) =  91

s =  8
hpsrt(s,2) =  35
npsrt(s,2) =  70
totstr(s,2) =  105

s =  9
hpsrt(s,2) =  50
npsrt(s,2) =  100
totstr(s,2) =  150

s =  10
hpsrt(s,2) =  50
npsrt(s,2) =  100
totstr(s,2) =  150

wortr = 1106
nsyvis = 40
nstrsn = 48
tonstr = 480
redtr =  1586
todtr =  796
dsscap =  1780
diff =  984
```

```
sum = 88
vissat(k,1) = 4
vissat(k,2) = 88

k =  5
sensor(k,4)=  .73ØØØØØØØe+Ø2
sensor(k,5)=  .183ØØØØØØe+Ø3
lwlim =  73
uplim =  183
losatn =  56
hisatn = 135
sum = 8Ø
vissat(k,1) = 5
vissat(k,2) = 8Ø

k =  6
sensor(k,4)=  .14ØØØØØØØe+Ø3
sensor(k,5)=  .266ØØØØØØe+Ø3
lwlim =  14Ø
uplim =  266
losatn =  117
hisatn = 193
sum = 77
vissat(k,1) = 6
vissat(k,2) = 77

k =  7
sensor(k,4)=  .14ØØØØØØØe+Ø3
sensor(k,5)=  .266ØØØØØØe+Ø3
lwlim =  14Ø
uplim =  266
losatn =  117
hisatn = 193
sum = 77
vissat(k,1) = 7
vissat(k,2) = 77

k =  8
sensor(k,4)=  .91ØØØØØØØe+Ø2
sensor(k,5)=  .244ØØØØØØe+Ø3
lwlim =  91
uplim =  244
losatn =  83
hisatn = 17Ø
sum = 88
vissat(k,1) = 8
vissat(k,2) = 88

k =  9
sensor(k,4)=  .2Ø8ØØØØØØe+Ø3
sensor(k,5)=  8.ØØØØØØØØ
lwlim =  2Ø8
uplim =  8
losatn =  144
hisatn = 4
sum = -139
vissat(k,1) = 9
vissat(k,2) = 125

k =  1Ø
sensor(k,4)=  .325ØØØØØØe+Ø3
sensor(k,5)=  .115ØØØØØØe+Ø3
lwlim =  325
uplim =  115
```

```
num =  10
maxsat = 264
nonsyn = 400

     27.00       6.90     294.80     241.00     350.00     120.00

     25.00      40.60      17.80     321.00      75.00     120.00

     30.00      35.00     242.10     187.00     297.00     120.00

    210.00      33.80     253.30     195.00     310.00     360.00

    220.00      35.70     128.60      73.00     183.00     360.00

    230.00      20.70     203.70     140.00     266.00     360.00

    951.00      20.70     203.70     140.00     266.00     100.00

    334.00       9.40     167.50      91.00     244.00      80.00

    369.00      42.60     288.50     208.00       8.00      80.00

    337.00      37.90      40.00     325.00     115.00      80.00

k =  1
sensor(k,4)=  .241000000e+03
sensor(k,5)=  .350000000e+03
lwlim =  241
uplim =  350
losatn =  169
hisatn = 259
sum = 91
vissat(k,1) = 1
vissat(k,2) = 91

k =  2
sensor(k,4)=  .321000000e+03
sensor(k,5)=  .750000000e+02
lwlim =  321
uplim =  75
losatn =  230
hisatn = 58
sum = -171
vissat(k,1) = 2
vissat(k,2) = 93

k =  3
sensor(k,4)=  .187000000e+03
sensor(k,5)=  .297000000e+03
lwlim =  187
uplim =  297
losatn =  137
hisatn = 219
sum = 83
vissat(k,1) = 3
vissat(k,2) = 83

k =  4
sensor(k,4)=  .195000000e+03
sensor(k,5)=  .310000000e+03
lwlim =  195
uplim =  310
losatn =  139
hisatn = 226
```

APPENDIX B

EXTENDED OUTPUT

```
*               print for each sensor, the individual sensor tracking capacit
*                       the individual sensor tracking requirement, and the
*                       difference between the two
*       end do loop
*       start do loop
*               print for each sensor pair the number of satellites visible
*                       to both sensors
*       end do loop
*       end subroutine print
*
**********************************************************************
c       start subroutine print
        subroutine print(vissat,dsscap,todtr,num,wkld,ovlp,redtr)
c-------------------------------------------------------------------
        integer i,j,num,vissat(15,3),dsscap,todtr,x,p,wkld(15,3)
        integer g,h,ovlp(2Ø,2Ø),redtr
c-------------------------------------------------------------------
        print*,'sensor no. 1 = Baker-Nunn, St Margarets'
        print*,'sensor no. 2 = Baker-Nunn, San Vito'
        print*,'sensor no. 3 = Baker-Nunn, Edwards'
        print*,'sensor no. 4 = GEODSS,     Soccoro'
        print*,'sensor no. 5 = GEODSS,     Korea'
        print*,'sensor no. 6 = GEODSS,     Maui '
        print*,'sensor no. 7 = MOTIF,      Maui'
        print*,'sensor no. 8 = Radar,      Altair'
        print*,'sensor no. 9 = Radar,      Millstone'
        print*,'sensor no. 1Ø= Radar,      Pirincilik'
        print*,'sensor no. 11= GEODSS,     Diego Garcia'
        print*,'sensor no. 12= GEODSS,     Portugal'
        print*
        print*,'Number of synchronous satellites visible to each sensor'
        print*
        print*,'Sensor number      Number of satellites'
        do 11Ø i = 1,num
                print*
                print 3Ø,(vissat(i,j),j=1,2)
 3Ø             format (' ',I6,21X,I6)
 11Ø    continue
c       end do loop
        print*,'Combined Deep Space Track Capacity = ',dsscap
        print*,'Total Deep Space Track Requirement = ',todtr
        print*
        print*,'Total Redundant Track Requirement = ',redtr
        print*
        print*,'Workload Distribution'
        Print*
        do 12Ø x = 1,num
                Print*,'Sensor number        No. of Required Tracks   Differe
                print 4Ø, (wkld(x,p),p = 1,3)
 4Ø             format (' ',I6,21X,I6,12X,I6)
 12Ø    continue
        print*
        print*,'overlap visibility array'
        do 13Ø g = 1,num
                print 5Ø, (ovlp(g,h),h = 1,num)
 5Ø             format (' ',2ØI5)
 13Ø    continue
c       end do loop
        end
c       end subroutine print
********************************************************************
********************************************************************
```

```
                          go to 245
                    end if
                    hisatn = t
                    print*
                    print*,'between',low,'east longitude'
                    print*,'and',high,'east longitude'
                    print*,'sensor no.',k,'and sensor no.',b
                    print*,'have overlapping coverage'
              end if
              if (n .eq. Ø .and. t .eq. Ø) then
                    ovlp(k,b) = Ø
                    print*
                    print*,'sensor number',k,'and'
                    print*,'sensor number',b
                    print*,'have no overlapping coverage'
              end if
 25Ø          if (n .ne. Ø .and. t .ne. Ø) then
                    sum = hisatn - losatn + 1
                    if (sum .lt. Ø) then
                          sum = Ø
                          sum = hisatn + (maxsat - losatn + 1)
                          ovlp(k,b) = sum
                    else
                          ovlp(k,b) = sum
                    end if
                    print*,'The number of visible satellites in'
                    print*,'the overlapping coverage between'
                    print*,'sensor number',k,'and sensor number'
                    print*,'is',ovlp(k,b)
              end if
 14Ø          continue
 13Ø    continue
        end
c       end subroutine ovrlap
***********************************************************************
***********************************************************************
***********************************************************************
*subroutine print
*       This subroutine will print the data calculated by program
*       dssnef.
***********************************************************************
*
*LOCAL VARIABLES
*  Type: Integer
*       i,j             matrix row and column counter
*
*       g,h             matrix row and column counter
*
*       x               sensor counter
*
*       p               colunm counter for wkld matrix
*
***********************************************************************
*
*ALGORITHM DEVELOPEMENT
*
*       start subroutine print
*       print sensor numbers and sensor names
*       start do loop
*             print number of synchronous satellites visible to each sensor
*       end do loop
*       print the combined deep space sensor tracking capacity
*       print the combined deep space satellite tracking requirement
*       start do loop
```

```
                        end if
                        losatn = n
                        t = maxsat
220                     if (high .lt. synsat(t,2)) then
                                t = t - 1
                                go to 220
                        end if
                        hisatn = t
                        print*
                        print*,'between',low,'east longitude'
                        print*,'and',high,'east longitude'
                        print*,'sensor no.',k,'and sensor no.',b
                        print*,'have overlapping coverage'
                end if
                if (lwlim .eq. lwbord .and. uplim .eq. upbord
     c                  .and. sensor(k,1) .ne. sensor(b,1)) then
                        n = 1
                        low = lwlim
                        high = uplim
                        if (high .ge. 360) then
                                high = high - 360
                        end if
230                     if (low .gt. synsat(n,2)) then
                                n = n + 1
                                go to 230
                        end if
                        losatn = n
                        t = maxsat
240                     if (high .lt. synsat(t,2)) then
                                t = t - 1
                                go to 240
                        end if
                        hisatn = t
                        print*
                        print*,'between',low,'east longitude'
                        print*,'and',high,'east longitude'
                        print*,'sensor no.',k,'and sensor no.',b
                        print*,'have overlapping coverage'
                end if
                if (n .ne. 0 .and. t .ne. 0) then
                        go to 250
                end if
                h = uplim - 360
                if (uplim .gt. 360 .and. lwbord .lt. h) then
                        lwbord = lwbord + 360
                end if
                if (lwbord .lt. uplim .and. lwbord .gt. lwlim) then
                        n = 1
                        low = lwbord
                        high = uplim
                        if (high .ge. 360) then
                                high = high - 360
                        end if
                        if (low .ge. 360) then
                                low = low - 360
                        end if
242                     if (low .gt. synsat(n,2)) then
                                n = n + 1
                                go to 242
                        end if
                        losatn = n
                        t = maxsat
245                     if (high .lt. synsat(t,2)) then
                                t = t - 1
```

```
                        print*
                        print*,'between',low,'east longitude'
                        print*,'and',high,'east longitude'
                        print*,'sensor no.',k,'and sensor no.',b
                        print*,'have overlapping coverage'
                end if
                if (upbord .gt. lwlim .and. upbord .lt. uplim) then
                        n = 1
                        low = lwlim
                        high = upbord
                        if ( high .ge. 360) then
                                high = high - 360
                        end if
170                     if (low .gt. synsat(n,2)) then
                                n = n + 1
                                go to 170
                        end if
                        losatn = n
                        t = maxsat
180                     if (high .lt. synsat(t,2)) then
                                t = t - 1
                                go to 180
                        end if
                        hisatn = t
                        print*
                        print*,'between',low,'east longitude'
                        print*,'and',high,'east longitude'
                        print*,'sensor no.',k,'and sensor no.',b
                        print*,'have overlapping coverage'
                end if
                if (lwbord .gt. lwlim .and. upbord .lt. uplim) then
                        n = 1
                        low = lwbord
                        high = upbord
                        if (high .ge. 360) then
                                high = high - 360
                        end if
190                     if (low .gt. synsat(n,2)) then
                                n = n + 1
                                go to 190
                        end if
                        losatn = n
                        t = maxsat
200                     if (high .lt. synsat(t,2)) then
                                t = t - 1
                                go to 200
                        end if
                        hisatn = t
                        print*
                        print*,'between',low,'east longitude'
                        print*,'and',high,'east longitude'
                        print*,'sensor no.',k,'and sensor no.',b
                        print*,'have overlapping coverage'
                end if
                if (lwlim .gt. lwbord .and. uplim .lt. upbord) then
                        n = 1
                        low = lwlim
                        high = uplim
                        if (high .ge. 360) then
                                high = high - 360
                        end if
210                     if (low .gt. synsat(n,2)) then
                                n = n + 1
                                go to 210
```

have no overlapping coverage

between 140 east longitude
and 183 east longitude
sensor no. 5 and sensor no. 6
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 5 and sensor number 6
is 19

between 140 east longitude
and 183 east longitude
sensor no. 5 and sensor no. 7
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 5 and sensor number 7
is 19

between 91 east longitude
and 183 east longitude
sensor no. 5 and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 5 and sensor number 8
is 53

sensor number 5 and
sensor number 9
have no overlapping coverage

between 73 east longitude
and 115 east longitude
sensor no. 5 and sensor no. 10
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 5 and sensor number 10
is 40

between 241 east longitude
and 266 east longitude
sensor no. 6 and sensor no. 1
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 6 and sensor number 1
is 25

sensor number 6 and
sensor number 2
have no overlapping coverage

between 187 east longitude
and 266 east longitude
sensor no. 6 and sensor no. 3
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 6 and sensor numbe 3
is 57

between 195 east longitude
and 266 east longitude
sensor no. 6 and sensor no. 4
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 6 and sensor number 4
is 55

between 140 east longitude
and 183 east longitude
sensor no. 6 and sensor no. 5
have overlapping coverage

between 140 east longitude
and 183 east longitude
sensor no. 6 and sensor no. 5
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 6 and sensor number 5
is 19

sensor number 6 and
sensor number 6
have no overlapping coverage

between 140 east longitude
and 266 east longitude
sensor no. 6 and sensor no. 7
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 6 and sensor number 7
is 77

between 140 east longitude
and 244 east longitude
sensor no. 6 and sensor no. 8
have overlapping coverage

between 140 east longitude
and 244 east longitude
sensor no. 6 and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 6 and sensor number 8
is 54

between 208 east longitude
and 266 east longitude
sensor no. 6 and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 6 and sensor number 9
is 50

sensor number 6 and
sensor number 10
have no overlapping coverage

between 241 east longitude

and 266 east longitude
sensor no. 7 and sensor no. 1
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 7 and sensor number 1
is 25

sensor number 7 and
sensor number 2
have no overlapping coverage

between 187 east longitude
and 266 east longitude
sensor no. 7 and sensor no. 3
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 7 and sensor number 3
is 57

between 195 east longitude
and 266 east longitude
sensor no. 7 and sensor no. 4
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 7 and sensor number 4
is 55

between 140 east longitude
and 183 east longitude
sensor no. 7 and sensor no. 5
have overlapping coverage

between 140 east longitude
and 183 east longitude
sensor no. 7 and sensor no. 5
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 7 and sensor number 5
is 19

between 140 east longitude
and 266 east longitude
sensor no. 7 and sensor no. 6
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 7 and sensor number 6
is 77

sensor number 7 and
sensor number 7
have no overlapping coverage

between 140 east longitude
and 244 east longitude
sensor no. 7 and sensor no. 8
have overlapping coverage

between 140 east longitude
and 244 east longitude

sensor no. 7 and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 7 and sensor number 8
is 54

between 208 east longitude
and 266 east longitude
sensor no. 7 and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 7 and sensor number 9
is 50

sensor number 7 and
sensor number 10
have no overlapping coverage

between 241 east longitude
and 244 east longitude
sensor no. 8 and sensor no. 1
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 1
is 2

sensor number 8 and
sensor number 2
have no overlapping coverage

between 187 east longitude
and 244 east longitude
sensor no. 8 and sensor no. 3
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 3
is 34

between 195 east longitude
and 244 east longitude
sensor no. 8 and sensor no. 4
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 4
is 32

between 91 east longitude
and 183 east longitude
sensor no. 8 and sensor no. 5
have overlapping coverage

between 91 east longitude
and 183 east longitude
sensor no. 8 and sensor no. 5
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 5
is 53

between 14Ø east longitude
and 244 east longitude
sensor no. 8 and sensor no. 6
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 6
is 54

between 14Ø east longitude
and 244 east longitude
sensor no. 8 and sensor no. 7
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 7
is 54

sensor number 8 and
sensor number 8
have no overlapping coverage

between 2Ø8 east longitude
and 244 east longitude
sensor no. 8 and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 9
is 27

between 91 east longitude
and 115 east longitude
sensor no. 8 and sensor no. 1Ø
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 8 and sensor number 1Ø
is 13

between 241 east longitude
and 8 east longitude
sensor no. 9 and sensor no. 1
have overlapping coverage

between 2Ø8 east longitude
and 35Ø east longitude
sensor no. 9 and sensor no. 1
have overlapping coverage

between 241 east longitude
and 35Ø east longitude
sensor no. 9 and sensor no. 1
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 9 and sensor number 1
is 91

between 321 east longitude
and 8 east longitude
sensor no. 9 and sensor no. 2
have overlapping coverage
The number of visible satellites in

```
the overlapping coverage between
sensor number 9 and sensor number 2
is 39

between 2Ø8 east longitude
and 297 east longitude
sensor no. 9 and sensor no. 3
have overlapping coverage

between 2Ø8 east longitude
and 297 east longitude
sensor no. 9 and sensor no. 3
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 9 and sensor number 3
is 76

between 2Ø8 east longitude
and 31Ø east longitude
sensor no. 9 and sensor no. 4
have overlapping coverage

between 2Ø8 east longitude
and 31Ø east longitude
sensor no. 9 and sensor no. 4
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 9 and sensor number 4
is 83

sensor number 9 and
sensor number 5
have no overlapping coverage

between 2Ø8 east longitude
and 266 east longitude
sensor no. 9 and sensor no. 6
have overlapping coverage

between 2Ø8 east longitude
and 266 east longitude
sensor no. 9 and sensor no. 6
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 9 and sensor number 6
is 5Ø

between 2Ø8 east longitude
and 266 east longitude
sensor no. 9 and sensor no. 7
have overlapping coverage

between 2Ø8 east longitude
and 266 east longitude
sensor no. 9 and sensor no. 7
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 9 and sensor number 7
is 5Ø
```

between 2Ø8 east longitude
and 244 east longitude
sensor no. 9 and sensor no. 8
have overlapping coverage

between 2Ø8 east longitude
and 244 east longitude
sensor no. 9 and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 9 and sensor number 8
is 27

sensor number 9 and
sensor number 9
have no overlapping coverage

between 325 east longitude
and 8 east longitude
sensor no. 9 and sensor no. 1Ø
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 9 and sensor number 1Ø
is 35

between 325 east longitude
and 35Ø east longitude
sensor no. 1Ø and sensor no. 1
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1Ø and sensor number 1
is 26

between 325 east longitude
and 75 east longitude
sensor no. 1Ø and sensor no. 2
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1Ø and sensor number 2
is 89

sensor number 1Ø and
sensor number 3
have no overlapping coverage

sensor number 1Ø and
sensor number 4
have no overlapping coverage

between 73 east longitude
and 115 east longitude
sensor no. 1Ø and sensor no. 5
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1Ø and sensor number 5
is 4Ø

sensor number 1Ø and
sensor number 6

```
have no overlapping coverage

sensor number 1Ø and
sensor number 7
have no overlapping coverage

between 91 east longitude
and 115 east longitude
sensor no. 1Ø and sensor no. 8
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1Ø and sensor number 8
is 13

between 325 east longitude
and 8 east longitude
sensor no. 1Ø and sensor no. 9
have overlapping coverage
The number of visible satellites in
the overlapping coverage between
sensor number 1Ø and sensor number 9
is 35

sensor number 1Ø and
sensor number 1Ø
have no overlapping coverage
```

APPENDIX C

SATELLITE DISTRIBUTION FILE

1.00	1.00
2.00	3.40
3.00	4.70
4.00	6.10
5.00	10.40
6.00	11.40
7.00	11.70
8.00	13.00
9.00	14.50
10.00	14.70
11.00	21.10
12.00	21.30
13.00	21.80
14.00	23.30
15.00	24.80
16.00	25.20
17.00	27.40
18.00	31.60
19.00	33.40
20.00	34.30
21.00	34.70
22.00	39.60
23.00	40.20
24.00	42.10
25.00	44.90
26.00	47.70
27.00	48.30
28.00	50.20
29.00	50.50
30.00	52.80

31.00	52.80
32.00	53.00
33.00	56.00
34.00	57.10
35.00	58.60
36.00	58.70
37.00	59.50
38.00	59.50
39.00	60.50
40.00	61.50
41.00	61.80
42.00	62.20
43.00	62.90
44.00	62.90
45.00	64.60
46.00	65.20
47.00	65.70
48.00	66.70
49.00	66.80
50.00	67.00
51.00	67.00
52.00	67.40
53.00	70.80
54.00	71.90
55.00	72.60
56.00	73.90
57.00	74.20
58.00	74.50
59.00	75.30
60.00	75.40
61.00	75.80
62.00	75.80

63.00	76.00
64.00	79.90
65.00	79.90
66.00	80.80
67.00	81.30
68.00	81.90
69.00	82.40
70.00	82.60
71.00	83.40
72.00	83.70
73.00	83.70
74.00	83.70
75.00	85.30
76.00	85.40
77.00	85.70
78.00	85.80
79.00	89.70
80.00	90.10
81.00	90.10
82.00	90.60
83.00	92.80
84.00	94.80
85.00	98.30
86.00	99.40
87.00	100.00
88.00	102.80
89.00	104.20
90.00	104.60
91.00	105.00
92.00	106.90
93.00	107.70
94.00	109.50

95.00	114.30
96.00	115.80
97.00	116.70
98.00	118.50
99.00	121.10
100.00	122.50
101.00	123.20
102.00	124.80
103.00	125.00
104.00	126.30
105.00	126.90
106.00	127.40
107.00	128.40
108.00	131.50
109.00	131.90
110.00	132.70
111.00	135.00
112.00	135.30
113.00	135.90
114.00	139.20
115.00	139.40
116.00	139.90
117.00	140.40
118.00	145.20
119.00	146.40
120.00	150.20
121.00	153.80
122.00	157.90
123.00	159.80
124.00	160.30
125.00	163.50
126.00	164.40

127.00	165.30
128.00	167.00
129.00	171.20
130.00	174.00
131.00	174.60
132.00	176.20
133.00	178.30
134.00	178.90
135.00	179.50
136.00	186.90
137.00	189.90
138.00	193.90
139.00	196.80
140.00	196.80
141.00	199.00
142.00	201.50
143.00	203.20
144.00	210.80
145.00	214.90
146.00	214.90
147.00	217.00
148.00	218.00
149.00	220.60
150.00	220.80
151.00	220.90
152.00	221.30
153.00	225.00
154.00	225.30
155.00	225.40
156.00	225.90
157.00	226.70
158.00	228.20

159.00	228.70
160.00	229.00
161.00	229.30
162.00	229.70
163.00	230.50
164.00	230.90
165.00	232.90
166.00	233.60
167.00	237.00
168.00	239.90
169.00	241.60
170.00	242.40
171.00	245.80
172.00	245.90
173.00	249.40
174.00	249.50
175.00	250.90
176.00	253.00
177.00	253.10
178.00	254.40
179.00	254.70
180.00	254.70
181.00	254.70
182.00	254.80
183.00	255.10
184.00	255.40
185.00	258.60
186.00	259.90
187.00	260.10
188.00	260.30
189.00	260.30
190.00	260.90

191.00	263.20
192.00	263.90
193.00	264.90
194.00	266.80
195.00	267.40
196.00	267.50
197.00	268.00
198.00	269.10
199.00	269.60
200.00	273.00
201.00	273.20
202.00	274.90
203.00	276.30
204.00	276.90
205.00	277.40
206.00	278.70
207.00	280.80
208.00	281.10
209.00	282.80
210.00	283.80
211.00	283.90
212.00	284.40
213.00	285.90
214.00	287.80
215.00	291.90
216.00	293.50
217.00	295.20
218.00	296.70
219.00	296.70
220.00	301.00
221.00	301.70
222.00	303.50

223.00	306.90
224.00	308.60
225.00	309.80
226.00	309.80
227.00	312.70
228.00	313.60
229.00	318.20
230.00	321.40
231.00	322.40
232.00	322.60
233.00	322.90
234.00	325.50
235.00	327.10
236.00	328.80
237.00	330.60
238.00	331.80
239.00	332.50
240.00	333.70
241.00	334.00
242.00	335.00
243.00	335.40
244.00	335.80
245.00	336.70
246.00	338.60
247.00	339.00
248.00	340.90
249.00	341.40
250.00	342.10
251.00	345.30
252.00	345.40
253.00	345.70
254.00	346.10

255.00	348.00
256.00	348.40
257.00	348.50
258.00	349.30
259.00	349.60
260.00	354.10
261.00	354.10
262.00	358.40
263.00	358.80
264.00	359.60

VITA

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The deep space satellite tracking network presently in operation is not capable of providing enough observations to monitor all deep space satellites at optimum levels currency. The major reason for this deficiency is the reliance upon the five GEODSS sensors for the bulk of the observations. All though only three of the five sites are presently in operation, the three in operation are only capable of providing 40% of their maximum tracking capacities. Because the GEODSS sensors are optical, they are limited to operation only during darkness and clear skies. If we assume that this 40% of maximum is to continue, the addition of the last two GEODSS sensors will only maintain the present capabilities since the Baker-Nunn cameras are scheduled to be shut down when the last two GEODSS sites are operational.

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As a tool ~~used~~ for the above analysis, a computer program was developed using Fortran 77 language. The program uses as inputs: the distribution of synchronous satellites, total deep space satellite size, sensor locations and sensor visibility limits. The program determines the number of satellites visible to each individual sensor, the number of tracks required for each sensor, identifies areas of overlapping coverage between adjacent sensors, and the number of satellites within the areas of overlapping coverage.

END

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